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A

TREATISE

ON

RAIL-ROADS

AND

INTERNAL COMMUNICATIONS.

COMPILED FROM THE

BEST AND LATEST AUTHORITIES.

WITH

ORIGINAL SUGGESTIONS AND REMARKS.

BY

THOMAS EARLE.

PHILADELPHIA:

SOLD BY JOHN GRIGG, No. 9 NORTH FOURTH STREET;
TOWAR, J. & D. M. HOGAN, No. 255 MARKET STREET.

Mifflin & Parry, Printers.

1830.

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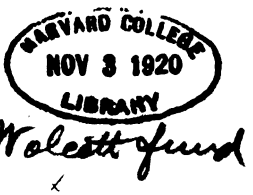

Eastern District of Pennsylvania, to wit:

BE IT REMEMBERED, that on the eleventh day of May, in the fifty-fourth year of the Independence of the United States of America, A. D. 1830, Thomas Earle, of the said district, hath deposited in this office the title of a book, the right whereof he claims as author, in the words following, to wit:

"A Treatise on Rail-Roads and Internal Communications, compiled from the best and latest authorities. With Original Suggestions and Remarks. By Thomas Earle."

In conformity to the Act of Congress of the United States, entitled, "An Act for the encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the time therein mentioned;" and also to an Act entitled, "An Act, supplementary to an Act, entitled, 'An Act for the encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the time therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

D. CALDWELL,
Clerk of the Eastern District of Pennsylvania.

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ERRATA.

Page 101, for 85, read 25, in the expense of transportation on turnpikes.
Page 37, at top, for fig. 7, read fig. 12.

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A TREATISE

ON

Rail-Roads & Internal Communications.

CHAP. I.

Of the plan and formation of a Rail-Road for the use of Horse Power.

The first thing to be determined in the formation of a Rail-road is the kind of power that is to be employed on it, whether horses, or steam engines. It is desirable not to use both kinds of power on the same road; because the graduation for each should be different, as will hereafter appear;—because the slow travelling of horses will present a serious obstruction to the free operations of locomotive steam engines, compelling them frequently to turn out, and occasioning delay and inconvenience; because a road for horses may be made of less strength and expensiveness than for steam carriages; and because the action of the horses' feet will throw dust and gravel on the rails, which it will be desirable to avoid on roads for engines, inasmuch as it increases the resistance, and the power required to move the wagons.* A further reason is, that the dust thrown on the rails, will be converted into mud, in wet weather, and will materially diminish the adhesion of the wheels of the locomotive engine to the rails.†

If the rail-road be intended for horses, it will then be proper to consider the choice of a route, between the two places to be connected by the road, and the mode of graduation which will be adapted to the most advantageous use of horse power.

* Wood on Rail-roads, p. 74. † Ib. p. 241.

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In relation to this subject, I shall propose a method, which it appears to me, may prove highly beneficial.

We are without as accurate experiments on the power of a horse, and the most advantageous mode of its application, as are desirable.

A horse's power is estimated by the weight which he can draw perpendicularly upwards out of a well, by a cord suspended over a pulley. Dr. Desaguliers estimates his power at 200lbs. at 2½ miles an hour, for 8 hours in a day: making 200lbs. 20 miles in a day.

Mr. Watt estimates it at 150lbs. moving 2½ miles an hour. Mr. Wood states it at 112lbs. 20 miles in a day.* On the Backworth Rail-Road, the horses exert a power, in ascending a plane of 2½ miles, varying from 113lbs. to 314lbs. The average power is 189lbs.; or it equals the power of a weight of 189lbs, suspended over a pulley. But in returning, less power is exerted.

It may, on the whole, be fair to take Mr. Watt's estimate of 150lbs. as the average performance of a horse, travelling 20 miles in a day, and working every day, with an exertion varying from 50 to 300lbs, but averaging 150lbs. If his exertion were constantly equal, his power would probably approach near the estimate of Dr. Desaguliers.

Having ascertained the average power which a horse can exert through the day, or for a certain number of hours, it is yet desirable to know what is the greatest force which he may occasionally exert for a short distance, without danger of injury, so that we may fix the greatest declivity allowable, on a rail-road, upon which certain weights are to be drawn. A horse, in England, carried on his back 1232lbs. eight miles without stopping. But, he cannot, by drawing, raise as great a weight perpendicularly, when suspended

* *Wood on Rail-Roads*, p. 236.—There is an evident error in Mr. Wood's calculation; as he has taken the average draught for about 20 miles; in about 5 of which the horse drew no load at all, but, if no brake were used, must have exerted as great a force in holding back the load, as in drawing it forward in other parts of the road. He takes the performance of a horse on a hilly road as the same with that upon a level road. If this were correct, a level road would have no advantage over a hilly one.

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over a pulley, as he can carry on his back. From some trials of the strength of a horse, against that of men, I should suppose the extreme weight a horse could raise by drawing (without the aid of any lever or other mechanical power), would be between 600 and 900lbs. The power generally exerted by dray and cart horses, on the steepest declivities in our cities, is probably at least 400lbs. The horses on the Team Colliery Rail Road in England, exert a power of 342lbs. regularly, on a plane of 500 feet in length. On the whole we may presume that 400lbs. is the greatest exertion that should be required of a horse, in extreme cases, and on short distances.

It is further desirable to know the rate of speed at which a horse can work most advantageously, in other words, whether it is easier for him to travel two miles an hour, exerting a force of 200lbs. on the load, or four miles an hour, exerting a force of but 100lbs.—Professor Leslie supposes the greatest effect to be produced at four miles an hour, or that a horse can draw more than half as much at that rate, as he can at two miles an hour. Mr. Wood supposes that the greatest effect is at the slowest rate of travelling. The latter supposition is probably the correct one. General experience seems to have proved that the most profitable horses for draught are those which travel slow. It is reasonable to suppose that the fewer times a horse travels over a piece of ground, to convey a certain quantity of goods, the better, provided the draught is not so great as to strain him: because the power exerted to transport his own body, is greater than that which he exerts on the load.

We will suppose then, that a horse's greatest effect can be produced in drawing at a speed of two miles an hour, or that he will draw more than double the weight at that speed, which he will do at four miles an hour, working an equal number of hours in a day.

A still further question remains, as to the number of hours in a day which a horse can work with most advantage. Can he work 8 hours per day exerting a force equal to 200lbs., with more, or with less ease, than he can work ten

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hours per day, exerting a constant force of 160lbs.?—From 8 to 10 hours is supposed to be the proper time for a horse to work: the more general and probably the more correct opinion is that it is not expedient to work a horse constantly for more than 8 hours in a day.* On the Killingworth Rail-Road, where the horses work through the day, it is found necessary to keep a spare horse, to four working horses, so that each horse rests one day in five.—Wood, p. 252.

We will suppose, therefore, until more accurate proofs are furnished, that a draught horse will do most work travelling 16 miles a day in 8 hours, and that at this rate he can exert a power of 200lbs. on the load, with as much ease as he could exert 150lbs. travelling 20 miles a day.

The most advantageous mode of applying this power, if practicable, without increased expense, would be upon a road perfectly level. But on most routes a level road is impossible; and where it is not so, the expense of preparing a level road would generally be greater than the expense of road and transportation combined, on an undulating track. The cost of preparing the first 13 miles of the Baltimore and Ohio Railway, for receiving the rails, is nearly 50,000 dollars per mile, the road being nearly a perfect level, while 2,000 dollars per mile would have prepared an undulating road.—The interest on the difference of cost, would pay both toll and transportation on about 250,000 tons of coal per annum, at the rate charged upon the Stockton and Darlington Railway.†

It is therefore a great desideratum to devise a mode by which a horse can perform about the same amount of work on an undulating, as he could do on a level road. This is to be effected by graduating the road in such manner that the power expended in ascents may be returned in propelling the wagons down descents and upon levels. To effect this, the horses must *ride*, in a spare wagon, wherever the ground isdescending. By doing so, the power required

* Tredgold considers 6 hours, the most advantageous.

† About one cent per ton a mile.

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upon an undulating road, of the best graduation, would be no more than on a level road, it being an established principle in mechanics, that a descending body will, by its gravity, exert all the power which was required to raise it to the height from which it descends.

The resistance to be overcome on a level rail-road consists entirely of the friction of the wagons. Now suppose a road to ascend for six miles distance at such rate that the power required to ascend would be twice as much as that required on a level road; and suppose it then to descend for six miles at the same rate. The power required to overcome gravity on the ascent would just suffice to overcome friction on the descent: and if the horse were to ride down the descent, the power expended on the 12 miles would be precisely the same as if he had drawn the same load 12 miles on a level railway. But were he to *travel* down the descent, the power required on the 12 miles, would be 50 per cent. greater than on a level way, if we suppose that one half the exertion is required to travel without a load, which is necessary to travel with one. But if we suppose with Wood [Wood on Rail-Roads, p. 92.] that seven eighths of a horse's exertion is expended in moving his own body, and only one eighth generally applied to the load, or that he will travel 7 miles, with a common load, as easily as 8 miles without one, then the labour of travelling the whole 12 miles would be 87½ per cent. more than if he were to ride in a spare wagon the six miles down the declivity. The only deduction from this advantage will be the power necessary to draw up the ascent the empty wagon, for the use of the horses in descending. Yet in most cases, the extraordinary exertion required to hold back the wagons, on the steeper parts of the descent, or to travel fast, to keep out of their way, would be more than equivalent to the labour of drawing the empty wagon up the ascent.

Under these considerations, such route and graduation for a road should be chosen as would enable a horse to exert his power most advantageously, and ride, without inconvenience, wherever the ground was descending. To prevent

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the trouble of frequently changing the horses, from drawing the wagons, to riding in one of them, the descents should be as long continued as may be convenient, interrupted only by short levels or light ascents, which may be overcome by the momentum acquired by the wagons in their previous descent. The descent should be very gradual except for a short distance; for in descending a long way, that is steep, a greater velocity is acquired than is safe, and if the wagons be checked by artificial means, a part of the power expended in ascending is wasted.

If, however, the descent is necessarily steep, it should, when practicable, be speedily succeeded by a level, or by an ascent upon which the surplus power acquired in the descent may be expended.

To understand the importance of this course, it should be considered that wagons descend a plane, subject to the same law that regulates the perpendicular falling of bodies through the atmosphere. If a plane be such that a wagon will descend 1 foot in the first second, it will descend 100 feet in 10 seconds, and the distance passed over in the 10th second, will be 19 feet, or 19 times as much as in the first second: And the descent will be 400 feet in 20 seconds, 39 feet of which will be in the 20th second, &c. The distance descended being always *in proportion to the square of the times* occupied in the descent. The only limitation of this law, arises from the increased resistance of the atmosphere, when the motion becomes rapid. This is theoretically true, and is proved to be practically so, by experiments made with wagons on an inclined plane. Wood, p. 199.

Bodies fall $16\frac{1}{12}$ feet perpendicularly through a vacuum in the first second. But on an inclined plane, if there were no friction, the distance passed over in the first second would bear the same proportion to $16\frac{1}{12}$ feet, as the height of the plane does to its length. Thus if the plane rose 1 foot in $16\frac{1}{12}$ feet of length, the body would descend 1 foot on the plane in the first second. If the plane rose but one foot in 100, then the body would descend but $\frac{1}{100}$th part of $16\frac{1}{12}$ feet in the first second.

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Knowing the declivity of any plane, we may ascertain the gravity of a body down it, from which, deducting the friction of the carriages, we can determine the time of their descent for any required distance, and the degree of velocity which they would acquire.

The friction of improved carriages, as we shall hereafter see, may fairly be estimated, not to exceed 1lb. in 300; or not more than 1lb. will be required, suspended over a pulley, to put a carriage weighing 300lbs. in motion, on a level railway. It would therefore require a descent of about 18 feet to the mile for the wagons to move of themselves, their gravity just overcoming their friction. We may then deduct the descent necessary to overcome friction, and determine the velocity of carriages down any plane, from the remaining descent.

The velocity acquired by a body in descending any distance, is, at the end of the distance, double the average velocity of the whole descent. The velocity acquired on any number of feet fall, *is in proportion to the square root of the falling distance:* and if we quadruple the descent, we double the velocity. Thus a body falling 16 feet in one second, acquires a velocity of 32 feet per second at the end of the first second; if it falls 64 feet, it acquires a velocity of 64 feet per second; and if it falls four times 64, or 256 feet, it acquires a velocity of 128 feet per second, &c.

The velocity per second acquired in any distance, is about eight times the square root of the distance, if no allowance be made for the resistance of the atmosphere.

If a plane descend 34 feet in a mile, for wagons having a friction of one pound in 300, we deduct near 18 feet for friction; leaving 16 feet for the operation of gravity. On such a plane 1 mile long, a wagon would therefore acquire a motion of 32 feet to the ~~minute~~ second, or about 30 feet, allowing for atmospheric resistance, being about the rate of 20 miles an hour.

If it be desired that the motion shall in no case exceed 20 miles an hour, in order to use power to the greatest advantage, a plane descending 26 feet to the mile, should be no more than two miles in length; a plane descending 34

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feet per mile, should be but one mile in length; one descending 50 feet to the mile, half a mile in length; and one descending 72 feet per mile, a quarter of a mile in length. A plane of an average descent of 20 feet per mile may be continued for any distance.*

It is not expected that these limits can always be attained at an expense which will not be more than equivalent to the advantages, yet they should be kept in view, and approached as nearly as may be conveniently practicable.

From Philadelphia to the ridge that divides the Conestoga from French Creek is about 40 miles, with an ascent of 700 or 800 feet, (according to the place of crossing) and from thence to the Conestoga near Lancaster is about 25 miles, with a descent of 400 to 500 feet. The descent is gradual in both directions, so that an average ascent and descent of 19 feet per mile might be attained for the whole distance; and horses might ride one half of the distance, in travelling both ways. The route, too, would approach nearly to the most direct one between the cities.

In selecting a route for a rail-road for horses, views of this kind should be operative.†

A second object will be to avoid the crossing of streams, requiring expensive bridges, and heavy embankments. The bridges, and the embankments at the ends of them, between Philadelphia and Lancaster, on the Columbia Rail-Road, will cost upwards of 3000 dollars per mile, nearly two thirds of which might have been saved by selecting the route above mentioned. The bridges on the Baltimore road are still more expensive. It is true the advantages of accommodating a manufacturing district may more than compensate for this expense; but the above instances are mentioned in illustration of a general principle of economy, to be applied where it is expedient.

If many streams are crossed, that regular graduation of ascents and descents which is desirable where horses are to be

* If friction be 1 pound to 300.

† On the Mauch Chunk Rail-way, the horses or mules ride; but the descent is too great for profit, for a horse could draw three times as many wagons up an ascent of 18 feet per mile, as up the Mauch Chunk Rail Road. The horses also ride on a portion of the Stockton and Darlington Rail-way, in England.

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used, cannot be attained, as every stream will form a ravine, or will have a hill upon each side of it.

It will be of great importance to select a route where the ground is firm, and if practicable, gravelly; as the artificial means necessary to make a proper foundation where the ground is of recent alluvion, are very expensive, and can never be so perfect, for preventing the settling of the supports and the production of inequalities on the surfaces of the rails, as a far cheaper foundation, upon solid earth.

It has been generally supposed, that the best course for a rail-way, is to follow the valleys of streams. It may be so in some cases, where the course of the stream is tolerably direct, where the country is very hilly or mountainous, and where the great amount of transportation is between two points both situate on the stream, and the chief tonnage is in the direction of the descent. The conveyance of coal from the head of the Schuylkill to its mouth, may possibly present a case of this kind. But, perhaps, as a general rule, it is not expedient to follow the valleys of streams; for the course of the road must be very crooked, or expensive excavation in rocks and abrupt hills will be encountered. If the immediate valley of the stream is followed, the foundation will generally be bad; and if the sides of the hills near the stream be followed, deep ravines from tributary rivulets must be passed, by making a great inequality in the road, or by expensive bridges and embankments, to preserve the level. The ridges which divide different waters, afford the best course and foundation for a road; and the best ground is found at or near the summits of such ridges, as it is there least broken by ravines. By following such ridges, a shorter route may generally be attained at less expense.*

It is needful to know the degree of variety which may be admitted in the rate of graduation, without material inconvenience. What is the extreme acclivity that a horse may surmount, without injury, for a short distance, with the same

* The Philadelphia and Columbia Rail Road rarely follows the valley of a stream on its whole route. Mr. Hopkins found the valley of the Conedoguinet Creek too crooked for the rail-way proposed to run from Harrisburg to Chambersburg.

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load which is proper for him to draw on the general route? We have already seen that a horse is capable, without injury, of an occasional exertion doubly as great as the average exertion which is proper for him to make for several successive hours. It will therefore require no diminution of the load, if a few places require such an exertion. Suppose then, the average ascent for several miles to be 18 feet per mile, with wagons having a friction of 1 pound in 300, then the friction and gravity would be about equal, or there would be required double the average power which would be necessary on a level road. But if we increase the acclivity, or steepness, it does not increase the friction of the wagons; therefore, taking the above cases, we would have to treble the acclivity, in order to double the draught.

Therefore, *omitting fractions*, 54 feet should be the extreme acclivity, where the average acclivity is 18 feet, and the friction is 1 pound in 300; and 81 feet should be the extreme acclivity, where the average acclivity is 27 feet, and the friction 1 pound in 200.

Then, on the average ascent, the power required to overcome friction, would be 1, and to overcome gravity 1.—Total 2. On the greatest ascent, to overcome friction 1, and to overcome gravity 3.—Total 4: or double that of the average. Thus we arrive at this

RULE.

On a rail road judiciously constructed for horse power, an occasional acclivity may be admitted, three times as great as the average acclivity: and such occasional acclivity will not make it necessary to diminish the load.

2. To what extent may the descent, where it is intended wagons shall run by their gravity, be interrupted by occasional levels or slight ascents?

Wagons descending at a velocity of 20 to 22 miles an hour, will have acquired a momentum equal to that of a body which has fallen about 15 feet perpendicularly through the atmosphere. This momentum would raise the same body 15 feet perpendicularly if there were no resistance.

Hence we find that any occasional level, or ascent, in the

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course where the wagons are to move by their own gravity and momentum, must be of such length that the amount of friction and gravity combined, will not equal the power required to raise the wagons a perpendicular height of 15 feet.

If the wagons have a friction of 1 in 300, then a level of three-fourths of a mile will not cause them to stop, if they have a previous velocity of 20 miles per hour: nor will an ascending plane of 18 feet rise to the mile, cause them to stop, if the plane be not more than three-eighths of a mile in length.

It will be desirable to have the declivity at the commencement of the descending ground, as great as can be any where admissible, in order that the wagons may speedily arrive at their requisite velocity. Afterwards the descent should be, as nearly as practicable, that at which the velocity would continue uniform, or just sufficient for the gravity of the wagons to overcome their friction.

From the foregoing observations we may deduce the following general

RULE.

On a rail road for horses where an ascent is necessarily to be surmounted, if the wagons have a friction of 1-300th part of their weight, the descent from the summit should commence at about 54 feet to the mile, and continue at that rate long enough to give the required velocity; after which the descent should continue as near 18 feet to the mile as the ground will admit.

An advantage of this method, not yet noticed, will be found, wherever the transportation, as is generally the case, is much greater in one direction than the other, by applying a greater number of horses on the part which is ascending in the direction of greatest transportation, and a less number where it is descending in that direction.

For instance: if the tonnage, including wagons, be twice as great from Lancaster to Philadelphia, as from Philadelphia to Lancaster, and the road can be made to descend gra-

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dually, from the summit, in both directions, and at the proper rate, then half as many horses will be required to perform the work between Philadelphia and the summit, as between the summit and Lancaster, and companies can so arrange their business as to have the wagons which are taken by two horses from Lancaster to the summit, taken by one horse from the summit to Philadelphia, and back. Thus a saving of needless travel to the horses, in addition to that before mentioned, will be attained. Trains of wagons going in opposite directions may meet at the summit, and the supernumerary horse will return with the other train of wagons.

Suppose the distance to Lancaster by a rail road to be 70 miles, 40 of which are between the summit and Philadelphia, and 30 between the summit and Lancaster. Suppose two roads are made, the one undulating for the whole distance, the other gradually descending from the summit in both directions: the ascents on each road being such that the gravity and friction are equal, or nearly so: and the tonnage to Philadelphia being double that toward Lancaster. Then take a number of wagons proper for the draught of two horses on the ascent from Lancaster to the summit. The power exerted by the horses on the load, would be precisely equal in both cases, whether the one road or the other were travelled; but the travel of the horses, or power exerted to move their own bodies, would be vastly different.

On the undulating road the distance travelled in going and returning, would be 140 miles by 2 horses, equal to one horse 280 miles.

On the gradually ascending road, the travel would be—

2 horses from Lancaster to summit, 30 miles, equal to 1 horse 60 miles,	60 miles.
1 horse from Philadelphia to summit,	40
Total,	100 miles.

Making only 100 miles travelling in the one case, against 280 miles in the other, the work performed being the same in both cases.

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A further advantage in travelling the gradually ascending and gradually descending road, would be found in the carriage of passengers, and goods, requiring speedy transportation. Travellers desire to go faster than a horse can travel with ease to himself, or profit to his owner, if the charges be moderate. By having the horses ride one half the distance, any admissible rate of speed for that portion of the distance might be had, so that the whole journey could be performed in less time.

Again, a horse can work advantageously but 8 or 10 hours in a day; but the driver may continue his easy task longer. The restings of the horse, during the descents made with rapid travelling, would consume about a sufficient time to make the number of hours worked the proper ones. Two hours time would be sufficient for descending the same distance which a draught horse would walk in 8 or 10 hours.

The general route of the road having been determined, from the foregoing considerations, the course, and mode of forming the foundation for the rails, in particular sections, will depend very much on the amount of business to be done, and on the question whether the tracks are to be double or single.

It has been a frequent error in the forming of canals, and probably will be so in rail roads, to make the work too expensive for the business which is done on the route. The consequence is that the stock is unprofitable, and the desire to render it productive causes so high tolls to be exacted, that the total cost of transportation is more than it would have been on a less perfect improvement.

As rail roads may be made double or single; winding or direct; greatly undulating, or nearly level; and made of cheap or expensive materials; they admit of a formation more proportionate to the business than canals.

If a road is not to form the connecting link between great commercial cities, and if there be neither extensive manufactories, nor coal nor iron mines on the route, the cheaper road will generally be the preferable one.

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The excavation and embankment on the most expensive mile, for the double rail way from Philadelphia to Columbia, is estimated to cost $16,995 69, while that on the least expensive mile, is estimated at only $399, being a difference of 42 to 1. The variations on the Baltimore and Ohio Road will be still greater.

Where the line of road is short, with an extensive business, a double way is preferable, for the accommodation of wagons passing at all hours in contrary directions. But if the line be long, with a small business, a single track will answer very well, as fixed places for meeting at particular hours can be provided, so that the wagons going in opposite directions will not interfere. There are many parts of country where the business will not pay for a double road, and yet a single one might be profitable, and afford a great accommodation to the inhabitants.

The expense of a cheaply constructed single way, will be less than half as much as that of a cheaply constructed double way: But the cost of a perfect single way is more than half that of a perfect double way.

The reason of this difference is, that a more perfect road will follow the straighter course, and be more nearly level, consequently requiring heavy embankments at ravines, and deep excavation at hills: while the less perfect road will pursue a winding course to obtain gradual ascents and descents, and will therefore be carried in a great measure upon the sides of hills.

A high embankment, or a deep cut, will cost nearly as much for a single as for a double way; because the width of cutting at the summit, or of embankment at the foundation, in such cases, will be far greater than the width of the road, and the additional width necessary for a double road will bear but a small proportion to the whole.

But where the road winds upon hill sides with only excavation sufficient for a level foundation, the amount required for a double road will be nearly nine times as great as for a single one: For, allowing for the space between the tracks, the double way will require a foundation nearly

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three times as wide as the single one; and therefore to form a level, the cutting next the hill must be nearly three times as deep, making about nine times the quantity of earth to be removed.

It will thus readily be seen, that if a rail-way be single, and of cheap materials, it will become expedient to extend its length considerably, by winding, where a proper graduation cannot otherwise be attained. But where it is double, and of expensive materials, it will be true economy to pursue a more direct route.

The shortness of the turns will materially affect the expense in many cases. The wagons hitherto used will not admit of very short turns without difficulty; but when we come to the article "wagons" we shall find that a kind has been invented which will probably obviate the inconvenience.

Of the foundation of the Road.

If the rails are not laid upon a foundation of sufficient firmness, the supports soon settle unequally, so that the rails become undulating, requiring a very irregular draught from the horses, and straining the wagons, by the shocks they receive at the meeting ends of rails of different slope.

Therefore in preparing the ground it should not only be made level crosswise, and of regular slope lengthwise, but of such materials, at least under the supports of the rails, that the regularity will be preserved. Wherever the ground is not solid, it is necessary to build walls, or fill trenches, or pits, with broken stone or gravel, for the support of the props upon which the rails are to rest. Such ground is often found in the valleys of streams: but when the road follows a hill side, near the summit, a removal of the soil from the surface to a moderate depth, generally lays bare ground of sufficient solidity for a rail way for the use of horses. Hence the importance of keeping the route as far as may be convenient, upon such ground, where the expense of preparing it to receive the rails is but triffling.

Of the Rails and their supports.

The ground having been properly prepared, the question

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of the proper kind of rails and supports to be used, arises. Where timber is scarce, and iron and stone abundant, it is considered advantageous to use rails entirely of *iron*, supported upon blocks of *stone*. Rail-ways of this kind may perhaps be expedient, even in America, if steam engines are to be used. But where horses are to furnish the power, it will generally be an important object to have a cheap work: and consequently wood, or wood and iron combined, will be preferred. We will therefore consider only the latter in this place, and will speak of the former in treating of ways for locomotive engines.

Wooden-rail ways have generally been made, in England, by laying sleepers of 4 or 6 inches square, across the road, at distances of 3 or 4 feet asunder, and fastening wooden rails 4 or 5 inches square upon the sleepers, by pins driven through the rails into the sleepers, in the manner shewn in plate 2. fig. 2.

But the mode at present preferred, is to cut grooves or mortices, across the sleepers, and fasten rails into them, by means of wedges or keys, as shown in plate 2. fig. 7.

The advantages of this mode are, that rails narrow and high may be used, and more firmly fixed than they could be by pins. This shape of rails is preferred to obtain great strength in the direction of the strain without a needless consumption of timber. There is less liability to split, in the rails, than if holes were bored through them; and if a rail be found defective, it can be removed by knocking out the keys, and a new one substituted without injury to the sleepers. If a sleeper become settled, the rail can be raised by driving a wedge under it, between the rail and the sleeper; and if the rails get out of true laterally, they can be regulated by driving wedges of the proper width on each side of the rail.

Locust or cedar wood is preferred for the sleepers, as being slow to decay. They are cut from saplings, or the large limbs of trees,* and hewn to a shape approaching to

* For a cheap work chestnut sleepers split from the bodies of trees are used, one of the flat sides being laid downward. Their shape approaches to three square, or triangular.

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squareness. Their cost, at Pottsville, is 8 to 10 cents each. They are generally placed at 4 feet distance from the centres of each other: leaving about 3 feet 6 inches between the sleepers.

The wooden rails are of sawed timber. White oak is considered the best. They are of different dimensions according to the views of the proprietors, or the weight of wagons to be used. Some are 3 inches wide by 5 in depth; some 4 by 6. The West Branch Road has them 4 by 7 inches; and it is intended, on the Norwegian Creek Road, to have them 8 by 10 inches. The two latter roads are intended to admit locomotive engines.

The transverse strength of timber, according to Barlow, may be calculated as follows:—

To find the weight required to break a beam when supported at both ends and loaded in the middle.

RULE.

Multiply the number in the following table of multiplicands by the square of the depth in inches, and that product by 4 times the breadth in inches. Divide the last product by the length in inches, and the quotient will be the weight. But if the beam be fixed at the ends, one half must be added to the weight.

TABLE OF MULTIPLICANDS.

English Oak, - -	1426
Canadian do. - -	1766
Ash, - - - -	2026
Beech, - - -	1556
Elm, - - -	1013
Pitch Pine, - - -	1632
Red Pine, - - -	1341
Fir, - - - -	1100
Larch, - - -	1127

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Example.

What weight will break a beam of Canadian Oak 3 inches broad, 5 inches deep, and 3 feet 6 inches between the props?

$$\frac{1766 \times 25 \times 12}{42} = 12{,}614 \text{ lbs. } \textit{Answer.}$$

If the ends be fast (as in rail roads) the pounds required will be 18,921—or upwards of 8 tons.

Two thirds of the above weights are considered safe for permanent loads.

As wagons weighing with their loading about two tons, will generally be used on rail ways for horses, the load on each wheel being ½ a ton and in no case over a ton, and as but one wheel will at one time rest between two sleepers, it will be seen that timber 3 by 5 inches, whatever the kind, is of strength amply sufficient, if the sleepers are sufficiently near; and this has been experimentally proved by practice.

On some roads, wooden rails without any covering of iron, except at crossing places and curves, are still used. Where the business of a road is small, and timber abundant, it may be expedient to save the expense of iron. In other cases iron plates should be used, to protect the timber from wear, as well as to render the motion of the wagons somewhat easier.

For these purposes plates of rolled iron are used, varying in dimensions from ¼ of an inch thick, by 1¼ wide, to ½ an inch thick, by 2 inches wide. The former will answer for a rail road for horses. If the business is extensive, the iron should be ⅜ thick.

If the rails be of *white-oak,* the iron may be fastened by wrought iron nails 3 or 4 inches long. But if the wood be not of a firm texture, the nails are apt to become loose and start upwards, so as to require frequent attention in driving them. In this case occasional bolts should be used, passing entirely through the wooden rail, and fastened by a nut and screw.

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The rails having been laid, and ironed, if to be so, the horse path is to be formed. For this purpose, gravel or broken stone is filled in between the rails, so as to cover the sleepers, and afford a dry and firm path. This can be done at little expense, if there be gravel on the route, as all the rest of the work being first finished, it may be conveyed along the line in wagons, on the rail road.

It is better to make the horse path outside the rails than between them, as it will exempt the work from the jarring occasioned by the action of the horses' feet on the sleepers, and will allow the rails to be left clear of earth, so they will decay less rapidly. On the Mauch Chunk Way, the path has been changed from between the rails to the outer side. Some expense of bridges and embankments may be saved by this mode, as the rails may be supported on posts over small streams.

Of the mode of Crossings or turnings out on Rail-Ways.

It is necessary on a single rail-way to have methods of turning out at the places of meeting, and on double ways it is necessary to cross from one track to the other, to pass slow travelling carriages.

The method is very simple and easy.

Plate 2, fig. 11, shows a method of crossings on a single rail-way by which each carriage, going in opposite directions, will take the right hand track, and afterwards return without any care.

Fig. 14, plate 2, shows the crossings on a double track.

At the places of crossing, there is a moveable pointed rail, as seen in plate 2, fig. 15, which being moved laterally against the side of the outer rail shown in the same fig. will shut up the direct passage and oblige the wagons to turn into the other track. When it is wished that the wagons should pursue the direct route, the passage between the pointed rail and the main rail is left open.

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Of Expenses of Road and Transportation.

It is difficult to calculate the general expense of a good Rail Road, without a previous examination of the route, as the cost may vary from $4000 to $50,000 per mile, for a double track, nearly straight and level. But when it is intended to have a single way of cheap construction, with the course accommodated to the nature of the ground, we may come very near the expense by knowing the price of timber and iron: as the excavation in such case will be tolerably uniform, and will generally not exceed, in the average, double the quantity necessary to form a suitable level for a road winding on a hill slope of 22½ degrees.

The cheaper single rail-ways of wood in Schuylkill county, have been made by contract, at a cost of two dollars a perch, or $640 per mile, including every expense of excavation, rails, and horse path, and they have been plated with iron at an expense of about $500 per mile.

The following may be a fair estimate for a single track of a moderately cheap kind, exclusive of bridges and drains:

Excavation and embankment for a foundation 8 feet wide, 3400 cubic yards, at 8 cents,*	272 00
1320 sleepers, at 8 cents each,	105 60
Rails 3 by 5 inches, of oak, 12,880 feet of timber, at $12 per M.†	154 59
Wedges to fasten the rails,	25 00
Preparing sleepers and laying rails	100 00
Occasional walling and broken stone for foundation, &c.	75 00
Grubbing, exclusive of value of timber,	50 00
Gravelling horse path,	100 00
Total, exclusive of culverts and bridges, (to be estimated according to the route,)	$882 19

* The cost of excavation where it is but of little depth, is but 6 or 7 cents per cubic yard; but where of great depth, it is 17 cents per cubic yard, owing to the difficulty of removing the earth.—See Major Wilson's Reports.

† The cost of timber in some places will not be one half the above, in others it will be double.

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Brought over,	$882 19

The above is for a wooden rail-way. If plated with iron the expense for iron $\frac{1}{4}$ by $1\frac{1}{4}$ inch may be estimated thus:—

Five tons iron at $75,	375 00
Nails,	40 00
Total,	$1297 19

If the iron be of larger dimensions, the expense can be calculated accordingly.

The transportation on such a road, if formed with ascents and descents upon the principle before mentioned, and with equal tonnage in both directions, may be reckoned as follows:—

If the horses exert a power of 200 lbs., and travel but 16 miles in a day, they will draw 13 tons to each horse up the ascent above mentioned, and riding 16 miles, the performance of each horse will be 13 tons, 32 miles, equal to 416 *tons* 1 *mile, in* 1 *day, for* 1 *horse:—friction being* 1 *lb. in* 300. This load includes the weight of the wagons.

CHAP. II.

Of the Plan and Formation of a Rail-Way for Locomotive Engines.

1. *Of the Route.*

For purposes of economy, the views which have been urged as proper in selecting a route for a rail-way for horses, should, in some measure, prevail in the choice of one for steam engines. Numerous streams, and the ravines occasioned by them, should be avoided, unless there are mills on them which will furnish business for the road to a very considerable amount.

It is however by no means so important for locomotive engines, to preserve long continued ascents and descents. On the contrary, a level road being impracticable at a reasonable expense, one composed of short undulations may be considered preferable to one of long continued ascents and descents, as

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the capacities of the steam engine are such, that a fund or reservoir of steam may be accumulated, while the engine and wagons are descending a declivity of moderate length by their own gravity, to enable the engine to surmount the next ascent with vigor and speed. But if descents are very long continued, the fire must be allowed to go down, or the steam to be wasted, by escaping at the safety valve.

As it is more difficult to constitute the carriages for steam engines than other carriages, so as to make short turns, without strain and injury both to the carriage and rails, it is the more desirable to make a straight road.

Hence it has always been considered a desideratum to devise a mode by which engines can ascend steep acclivities, and it has been an inquiry of interest, what rate of ascent is admissible. To overcome ascents, various plans have been devised, one of which, by Mr. Blenkinsop, at the Middleton Colliery, near Leeds, was to obtain the progressive motion of the engine by means of a large cog wheel, running in a toothed or rack rail. See plate 1, fig. 3. This mode has been many years in use on the road from Middleton to Leeds. Another method was that of Mr. Chapman, of a chain fastened to the summit of the hill, and descending to its foot, by means of which the engine ascended, aided by cogs running in the links of the chain.

But the expensiveness of these methods, and the increased friction they occasion, has prevented their general use; and it is considered preferable so to graduate the road that the carriages will ascend by the adhesion of the wheels. For when these wheels are moved by the engine, they must slip round on the rails, or must roll forwards; and whenever the load and ascent require less power to ascend than is equivalent to the friction which would arise from the slipping of the wheels on the rails, the carriages will proceed onwards; but if the load, or gravity, exceeds the friction which would arise from the slipping of the engine wheels on the rail, then the carriages will stand still, the engine carriage wheels being moved round without proceeding forward.

It is necessary therefore to ascertain what is the amount of

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adhesion to the rails, and in what way the greatest adhesion can be attained; and then graduate the road accordingly, so that the proper loads may be carried.

Mr. Wood, in his treatise on Rail-Roads, p. 242, 245, and 246, has given it as a maxim of general application, that the *adhesion of the wheels to the rails is in proportion to the weight of the engine.* And it was probably upon this supposition that the proprietors of the Stockton and Darlington Railway were induced to use engines weighing near 12 tons. But Mr. Wood's position is very erroneous; at least in its practical application.

It is true that the friction, or resistance, would be in proportion to weight, if the rubbing surface, or diameter of the rails, and rims of the wheels, were always increased, proportionately with the weight. But this was not contemplated.

Recent numerous and interesting experiments on friction, made by Mr. George Rennie of the Royal Society, London, will set the subject in a clear light.

He tried various metals sliding over a level surface of metal, until the two surfaces abraded each other; and ascertained the proportion of friction to weight, with different weights upon each square inch of rubbing surface.

The following are the results of cast iron upon wrought iron.

Weight upon 1 inch area of rubbing surface. Cwts. and decimals.	Proportion of friction to weight.
.09	1 to 6.36
1.66	1 " 3.63
2.00	1 " 3.42
2.33	1 " 3.11
2.66	1 " 3.04
3.00	1 " 3.00
3.33	1 " 2.85
3.66	1 " 2.83
4.	1 " 2.74
4.33	1 " 2.73
4.66	1 " 2.73
5.	1 " 2.72
5.33	1 " 2.72
5.66	1 " 2.72
6.00	1 " 2.66
6.33	1 " 2.30

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At 6.33 cwt. on the square inch, the iron was abraded.

It appears, from these experiments, that the adhesion of iron surfaces is not always in proportion to the weight pressing on them, but depends also on the proportion of weight to rubbing surface: That the adhesion with about 13lbs. on the square inch is less than 16 per cent. on the weight, while with 709lbs. on the inch, the adhesion amounts to upwards of 43 per cent. on the weight; and no greater adhesion than the latter can be obtained.

As it will not be desired to destroy the wheels and rails by abrasion, it would seem that no increase of weight beyond 709lbs. on each inch of the surface of the wheels in contact with the rails, would be of practical utility for promoting the locomotion of the engines. Yet, as mud upon the rails, in wet weather, acts in some degree like oil, in diminishing adhesion, a load of 10 cwt. on the inch might be desirable at some times, to obtain the greatest practicable adhesion without abrasion. It would seem that any increase of weight beyond this amount, would be positively injurious, as the additional weight of the engine to be moved up the ascent, would diminish, to the same extent, the power of drawing wagons attached to it.

The amount of adhesion for practical purposes, is therefore a fraction over 43 per cent. on 709lbs. or amounts to 305lbs. upon every inch of surface, on the wheels, in contact with the rails.

If we suppose the surface on each wheel, in contact with the rails, to extend half an inch longitudinally on the rails, owing to their deflexion under the weight of the engine, so that if the wheels are two inches wide we have 1 inch of surface, to each wheel, in contact with the rails; then we arrive at the following conclusions.

1. On rails two inches wide we obtain an adhesion equivalent to 305lbs. for each wheel of the engine, which is so connected with the machinery that it must revolve when the engine is in motion.

2. On rails 3 inches wide, we have an adhesion of $452\frac{1}{2}$lbs. to each wheel.

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If the engine carriage have 6 wheels properly connected with the machinery, the total adhesion will be 2745lbs. if the rails are 3 inches wide; or 1830lbs. if they are 2 inches wide.

If the engine carriage have but 4 wheels, connected and revolving with the machinery, then the adhesion will be 1830lbs. on rails 3 inches wide; and 1220lbs. on rails 2 inches wide.

That these results are within bounds may be presumed from an experiment of Mr. Wood (Wood on Rail-roads p. 243), in which he found that an engine having 4 wheels, adhered to rails $2\frac{1}{2}$ inches wide, with a force of 1810lbs. in dry weather; or raised as great a weight, including that of the engine, up an ascent of 1 foot in 100, as would be raised by 1810lbs. suspended over a pulley.

From these premises, it follows that the greatest weight of engine, and water in the boiler, desirable for purposes of locomotion, if the engine have 6 wheels, is $4\frac{1}{2}$ tons, on 3 inch rails; or 3 tons on 2 inch rails: Or if the engine have but 4 wheels, the weight of the engine should be 3 tons on 3 inch rails, and 2 tons on 2 inch rails.

Suppose then it be intended to produce the greatest effect in overcoming ascents, for which purpose the engines are to have 6 wheels, and weigh $4\frac{1}{2}$ tons, the rails being 3 inches wide.

It will be desirable to have the weight carried, amount, in all, to ten times the weight of the engine, or 45 tons, including the engine; as with such a weight, the engine may have an average speed of at least ten miles an hour.

The weight being 45 tons or 100,800lbs. the friction of the wheels, if at 1lb. in 300, will be 336lbs., which deducted from 1830lbs. (the adhesion of the wheels) leaves 1494lbs. the power to be applied to overcome the gravity of the carriages on an ascending plane. The weight 100,800lbs. being divided by the power, 1494lbs. gives a quotient of $67\frac{102}{1494}$. So that the power will raise the load up an ascent of 1 foot in $67\frac{1}{2}$ feet nearly; equal to an ascent of $79\frac{3}{4}$ feet to a mile.

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Whence we may deduce this general

RULE.

If the whole weight of Engine carriages and load, be 45 tons, with six wheels to the engine, or 30 tons with four wheels to the engine, the engines weighing $4\frac{1}{2}$ tons in the former case, and 3 tons in the latter: then the greatest admissible ascent will be 1 foot in $67\frac{1}{2}$ feet or $79\frac{3}{4}$ feet in the mile, the rails being 3 inches wide.

If the rails be narrower, or the ascent greater, the load must be reduced nearly in the same proportion, a small allowance being made for the saving of friction by the less load.

The ultimate conclusion is, that occasional ascents, of any rate not exceeding 80 feet to the mile, are admissible* in the direction of greatest transportation.

If the transportation is chiefly in one direction, the ascents in the direction of the empty carriages, may be considerably greater, according to the proportion of tonnage in that direction, compared with the other. As a general rule, ascents of 1 in 50, or 105 feet to the mile, will be admissible in the direction of least transportation.*

I am aware that in England it has been found that an engine would draw something less than half the weight up a plane, when the weather was damp, and the rails covered with mud, which it would do when the weather was quite dry, or quite rainy.

This difference is due partly to the increased resistance which the mud occasions to the motion of all the wagon wheels in the train, and partly to the diminution of adhesion of the engine wheels, produced by the mud acting as an unguent.

But as the weather, in America, is generally either dry or absolutely rainy; as the rails can be kept free from dust, and the mud which it would make, by a simple mode, which will

* By admissible, I do not mean expedient, unless in some peculiar cases. These calculations are based upon wagons whose friction is $\frac{1}{300}$th part of their weight. A reduction of friction will make an alteration of graduation expedient.

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hereafter be mentioned; and as the load above allowed to be drawn by the engine, viz. ten times its weight, is much greater than is usually calculated, we may still conclude the foregoing graduation to be admissible in extreme cases.

Having ascertained the practical rate of ascents for locomotive engines, it will become a question what kind of graduation is the best.

1. Shall a winding course of increased length be chosen, to avoid hills, or at least abrupt ascents? 2. Shall a straighter course be pursued by passing through hills by deep cuts or tunnels? 3. Or shall the road pass tolerably straight, going over the hills by an ascent of considerable steepness?

The inconveniences of the first course are, that the increased length of the road will require an increased expenditure in the iron, and stone, or wood; and this expenditure will require renewal to a greater or less extent in a few years; that it being difficult, if not impracticable, to adapt locomotive engines so as to make short turns, or, indeed, any turns without increased friction, strain and wearing, on both the wheels and the rails, the carriages and road will be rapidly deteriorated if the turns are frequent or abrupt; and the additional miles travelled, and consequent additional friction and decay of carriages, will be of some moment.

The objections to the second course, are, that in most cases deep cuts and tunnels are so expensive, that the interest on their cost will be more than equivalent to the whole expense of tolls and transportation by a different mode.

The inconvenience of the third mode consists principally in the loss of power, where the ascents are so steep and long continued, that the wagons would attain too great a velocity if not checked, in descending; and consequently, the power expended in ascending, will not be fully restored in descending.

Which of these inconveniences is to be preferred, will depend very much on the nature of the country and the amount of transportation which can safely be expected, and will

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therefore be a subject of calculation in each particular case, requiring much skill and care in the engineer.

Where the amount of tonnage will be very great, it may be true economy to expend a sum in straightening the road and avoiding acclivities, which would be absolute extravagance where the transportation will be small in quantity; for each ton of goods should pay its share of the expenditure, and the shares will be greater or less according to the number of tons passing.

In estimating the amount of transportation, there will be great danger of rating it too high. Rail-roads are not like canals, limited by the number of water courses, and the quantity which they supply; but they may be made through any part of a country; and the desire of citizens of every section to be accommodated, will cause them to become numerous, and lessen the amount of tonnage on the first established roads.

The safest course, therefore, is to avoid heavy expenditures; and it follows, that in most cases, a road of liberal graduation of ascents and descents, avoiding many windings and deep cuts, is preferable.

Although the engines on such a road will draw lighter loads, yet they may travel with the greater average velocity, so that the cost of transportation, exclusive of tolls, will be but little greater. And if the speed of engines for burden be great, they will obtain a handsome income from the carriage of passengers, and the employment of distinct engines for that purpose will be dispensed with, or will be very limited.

Steam power is admirably calculated for conveyance on undulating roads; for as the engines will admit of the most rapid or the slowest motion, according to the quantity of steam furnished, and resistance encountered, they may travel fast on a level, and slowly up hills, with an equal expenditure of steam; or an extraordinary supply, to give an increased pressure on the piston upon short ascents, may be often attained by shutting the steam off, and husbanding it,

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on previous descents. If descents be very long continued, the fire may be allowed to subside.

The greatest rate of ascending graduation upon any part of the route, where locomotive engines are to be used, having been fixed, it will generally not be advisable to encounter much increase of length or of expenditure, in any other part of the route, if it can be avoided by a similar graduation. For the graduation at one or two extreme points must regulate the load for the whole route, and the same graduation at other points will consequently not interfere with the tonnage carried.

A liberal graduation is of great advantage for the crossing of streams and ravines; for the expense of passing these by long and high bridges and heavy embankments to make the road nearly level, is enormous. The bridges, and embankments at the ends of bridges, on the Rail-way from Philadelphia to Columbia, are estimated to cost about 50 per cent. more than all the other preparation of the road for the reception of the rails. The passage over streams on the Baltimore and Ohio route, has been still more costly.

If the road descend into the valley of a stream, at a rate of 1 foot in 67, all the impetus acquired in the descent, and all the steam generated in the time, may be expended in aiding the ascent of the hill on the other side, for these hills will generally not be so long as to require any check to the impulse of gravity, nor to prevent the saving of all the steam produced. 79 yards to the mile

Where a country is generally level, as between Camden and Amboy, (N. J.) it may be expedient to encounter a very heavy expenditure, at a few places, rather than adopt a high rate of graduation; because the low rate will be nearly as cheap as the higher one, on most of the line; and it will be of advantage to carry as heavy loads as practicable, and travel slower, so as to save the expenditure of steam in transporting the engine twice over the ground where once may answer.

But hilly and mountainous countries present a case widely different, calling for a different policy. If coal be

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abundant and cheap on the route, the advantages of costly excavations will not counterbalance the expense, unless the business of the road be very great indeed.

Of Single and Double Tracks.

The route and rate of graduation being fixed, the question of single or double tracks, if not already determined, will arise.

The inconveniences of a single way will be still less with engines than with horse power; and far less than those of locks on canals. The considerations already urged in favour of economy, will apply to this question. It is further to be considered, that in a country of sparse population, the means at command will not always admit of that amount of expenditure, which, with unlimited capital, would be expedient. If the road is to be at the expense of the government, it should be considered whether a great expenditure in one section of country will not interfere with that justice and equal providence toward other sections, which ought to be maintained.

For the transportation of goods to a moderate amount, a single way will answer every purpose about as well as a double one. Engines can leave particular points at certain hours, and arrive at other points at fixed hours, each engine taking such weight as its ascertained capacity will enable it to carry at the desired speed.

For instance, take the distance between one of our Atlantic cities and Pittsburg, suppose a distance of 320 miles. If trains of wagons were to leave each city every morning, and travel the distance in 4 days, meeting places would be required every 40 miles. If wagons should leave each city, at both morning and noon, and arrive at both noon and night, the places of meeting would be every 20 miles, at fixed hours.

As great a quantity of goods could be conveyed, in this way, on a single rail-road, as on an ordinary canal. At each place of meeting, a few miles of double way should be made, that the course of the vehicles should be uninterrupted. Oc-

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casional places should also be fixed, for turning out, in case of accident, or failure of an engine and its train to arrive in due time.

Arrangements of this kind are inconsistent with the *beau-ideal* of travelling. The imagination delights in freedom from obstructions, and from the restraints of fixed rules. But we are compelled to submit, in practical matters, to the curb of reason. The question, in many cases, will be between a single rail-road and none at all. In such cases there can be little hesitancy.

Wherever the amount of tonnage is great, the double way is certainly to be preferred, as it will afford a means of continuing business, while one of the tracks may be undergoing repairs, and will admit of unrestricted freedom in hours of departure and arrival. More especially in the immediate vicinity of large cities, the accommodation of passengers by leaving at all hours, may be an object which will go far toward compensating the cost of the additional set of tracks.

Where the funds at command are limited, it may be well, in many cases, to construct the bridges, and general foundation of the road, so as to admit of double tracks; and lay down but a single track at first; adding the other, after increased business, or enlarged funds, shall have rendered it desirable and convenient.

Of the Rails, their Supports and Foundation.

The first kind of rails entirely of iron, that were used, were what is called the *plate-rail.* These were introduced in England about the year 1767. They were of cast iron, about 4 inches broad, with an upright ledge 2 or 3 inches in height, on the outer side, to keep the wheels from running off. Plate 2, fig. 9, represents a view of an end of one of these rails.

This kind of rail is used on some roads to the present day.

But a kind, called the "*edge rail,*" introduced by W. Jessop, an eminent engineer, in the year 1789, is now pre-

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ferred. The chief distinction in principle between the plate and the edge rail, is, that the latter, instead of having the upright ledge on the outer side, is smooth at the surface, and the ledge or "*flange*," is upon the inner edges of the rims of the carriage wheels.

Plate 2, fig. 10, represents a view of *an end* of one of the edge rails.

This rail is of great depth to give the greatest strength in proportion to the weight. It swells out at the bottom, for the purpose of increasing the strength. And it swells out at the top, to the width of 2½ inches, as generally made, for the purpose of giving a suitable width of surface for the wagon wheels to run upon. This rail is also of greater depth and thickness, midway between the supports, than at and near them, because more strength is required in the former place.

The edge rails were at first made of cast iron, 3 or 4 feet in length; but in 1820, Mr. John Birkinshaw, of Bedlington, England, invented a mode of rolling them of the desired shape, out of wrought or malleable iron, which is preferred, as less liable to break, and requiring but about half the weight of the cast iron; 56 lbs. to the yard being the proper weight for the latter, and 28 lbs. for the former.* One advantage of the malleable rail, is, that it may be made 15 or 18 feet in length, extending over several blocks or supports, thus diminishing the number of joinings, and the consequent liability of shocks to the wagons, from unevenness at the meeting ends of two rails.

The rails, whether of cast or of wrought iron, rest in cast iron chairs, which chairs rest on stone blocks to which they are fastened by wooden pins, driven into holes drilled in the stone. The cheeks of the chairs pass up the sides of the rail, which is fastened by a pin passing through both.

Plate 2, figs. 3 and 4, representing a top and side view of the rail and its supports, will give an idea of the form of the chairs and stone blocks.

* For engines weighing 7 tons. For the improved engines, lighter rails may be used.

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The rails, where two ends meet, were at first fastened to the chair by two separate pins driven one in each rail, as as shown in plate 2, fig. 7.

But this mode allowed the ends of the rails to become uneven, whenever the stone support settled more on one side than the other, and thus very injurious shocks were given to the wagon wheels.

This inconvenience has been in a great measure remedied by having the ends of the rails meet with a half lap, one pin passing through both rails; or by having the ends square, but fastened by a single pin through a hole made at the meeting of the ends, by a semicircular cavity in each rail. Plate 2. figs. 4. and 6. show the first mode, in a top view: And plate 2. figs. 3. and 5. the second mode, in a side view.

To prevent the stone blocks from settling unequally, a pit is excavated, and filled with broken stone to constitute the foundation of each block. Yet no mode has been used which altogether avoids the difficulty of one stone settling more than another, and rendering the way uneven.

The Baltimore and Ohio Rail-Road has rails intended for locomotive engines, formed of wood plated with iron, supported on sleepers, to which the wooden rails are keyed, as already mentioned, in the mode of forming a road for horses, page 20. The sleepers are supported on broken stone.

This method will probably form a way less liable to become and remain uneven, than the English mode of iron and stone, above described. For as both the wooden rails, and the iron plated on their surface, may be 12 or 16 feet long each, and extending over several sleepers, the joinings of the wood and of the iron may be always over separate sleepers, and the iron being firmly bolted to the wood, the continuous wooden rail will keep the iron even where it is joined, and the continuous iron rail will keep the wooden ones even at their joinings, in like manner: The joinings being as shewn in the top view in plate 2. fig. 7.

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a shows the joining of two wooden rails, and *b* the joining of two iron plates: the wood meeting over one sleeper, and the iron over another.

If a wooden sleeper be found to have settled, it will not be difficult to drive a little gravel under its end, so as to raise it to the proper level: or a wedge may be driven under the rail, between it and the sleeper.

The iron used on the Baltimore and Ohio road is 2 inches wide, by half an inch thick, the ends of each plate being cut obliquely as shown in the drawing.

These are probably as small dimensions as it will be expedient to have the iron of, in any case. But wherever the road has a considerable ascent, the iron should be at least 3 inches wide, to give a greater adhesion to the engine wheels, which should have proportionate width.

It might be expedient to have the iron 3 inches wide for the whole distance, on a road of great business, as it would be less likely to wear the wagon wheels into grooves, and the pressure being extended over a larger surface of the wooden rails, the whole work would be steadier and stronger.

It is said that extraneous matters are more apt to lodge on a broad rail. But a couple of brushes might easily be fixed to the front wagon of each train, so as to keep the rails swept. Three inches is less than the width of the plate rails which have been long used in England.

Maj. John Wilson and Mr. N. S. Roberts have proposed for the Columbia and Alleghany Rail-ways, to use stone supports with wooden rails.

The kind of supports proposed by Mr. Roberts are 2½ feet long by 20 inches square, and are estimated to cost 70 cents each, which would make the expense fourteen times as much as the wooden sleepers used at Pottsville. Those proposed by Maj. Wilson are not particularly described, but are less expensive.

When it is considered that cedar sleepers (such as are used on the Baltimore and Ohio road) will probably last, on the average, forty years, and that the mode of keying

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the rails into wooden sleepers, is preferable to that of pinning them to stones, there cannot be much hesitation, where wooden rails are used, in giving a preference over stone to cedar or locust sleepers, if to be had at a moderate price.

As the strength, firmness and steadiness of the rails, are of great importance, where locomotive engines are used, it may probably be found advantageous to have the sleepers, where they are of wood, placed at no greater distances apart than two or three feet. Then a little depression in an occasional sleeper will not so much affect the evenness of the road; as the other sleepers will support the rails. If the sleepers are numerous, the rails may be of less strength, so that the whole expense will not be materially different. The deflection of the rails under the weight of the engine and carriages, if the sleepers are far asunder, will certainly add to the power required to effect locomotion.

As it will be desirable to the reader to know the various kinds of rail-roads proposed by different engineers, we will here mention several:

Plan of Mr. Hayward, *for Rail-road from Boston to Providence.*

Foundation, to be two walls of stone laid in a trench, and rising to or near the surface of the ground. The walls to be 2 feet wide, and extend in depth 2½ feet below the surface, so as not to be affected by frost.

Rails, to be of hewn stone and iron combined. Blocks of hewn granite 5 to 10 feet long, and about 1 foot square, to be laid as rails the whole length of the road. Upon these stones, iron plates 2 inches wide, and 3-8ths of an inch thick, are to be fastened by iron bolts 3 inches long, and 3-8ths of an inch thick, driven into holes drilled in the stone.

This kind of road will be a very firm and durable one; and perhaps the most economical where timber and iron are dear, and stone abundant. It has been suggested that the iron bolts would not adhere in the stone; but it would not be difficult to have the holes drilled, with a little enlarge-

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ment at the bottom, and the bolts pointed in such manner that they would roll up, or clench at the lower extremity.

Mr. N. S. Roberts' *Plan for a Double Railway over the Alleghany Mountain, in Pennsylvania.*

Prepare stone supports about 20 inches square and about 2½ feet long, with the upper end of each properly cut, and drilled 8 inches deep, to receive a wooden plug. Place these stones in four parallel lines and 5 *feet apart*, in the direction of the road; the upper or cut end of each to be level with the pavement of the road. On these, place the side rails of locust timber, 6 by 10 inches square, and 15 feet long, to be secured to the stone supports by inch bolts driven through into the wooden plugs in the stones. Upon the inner edge of these side rails of each set of tracks, plates of rolled iron, 2 inches by ½ an inch, are secured by spikes or screws (counter sunk) once in about 3 feet.

The above plan would probably constitute a good road; but the expensiveness of the stone supports (calculated at 70 cents each) is objectionable. And it may be doubted whether the distance of the supports asunder, viz. 5 feet, is not greater than is expedient.

Mr. Wm. R. Hopkins's *Plan for a Railway from Harrisburg to Chambersburg, Pa.*

"After the road is properly levelled and graded, locust sleepers, 3 by 6 inches, are to be laid at right angles to the road, at the distance of 8 *feet apart*, and to be bedded on broken stone, so that a sufficient coating for the formation of the horse path may be formed over them. *Locust* blocks are to be pinned on these, their upper surfaces being level with the horse path; upon these *oak* scantling are to be secured, and the iron rails are spiked to the timbers. The iron is 3-8ths by 2 inches."

The above plan was for the use of horses. Probably Mr. Hopkins would propose a different one for locomotive engines. One advantage of the plan, is, that the horse path would be easily made, and would not approach too near the

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surfaces of the rails. The disadvantages are the great number of pins required in the work, which would be liable to start from their places in consequence of the jarring occasioned by the wagons; and the great distance (8 feet) between the supports.

Plan of Mr. Moncure Robinson.

Cubes of stone 2 feet square, to be embedded on broken stone 7 feet apart from centre to centre, in the direction of the rail-road.

Upon these, sills or sleepers of locust or white oak, 9 feet long and 12 inches square, to be bolted by pins driven into holes drilled in the stone blocks.

The wooden rails to be 8 by 12 inches, and keyed into the sills or sleepers. Upon these, iron rails or plates, having a cross section of $1\frac{4}{10}$ inches, are to be fastened by spikes $5\frac{1}{2}$ inches long.

This is intended for engines weighing $6\frac{1}{2}$ tons. For engines of 3 or 4 tons weight, Mr. Robinson would undoubtedly reduce the size of the timbers and irons.

It has been proposed to use, for supports, wooden posts, cut from the trunks of trees, and set to the depth of 2 or $2\frac{1}{2}$ feet in the ground, so as to have a solid foundation below the influence of frost; the part immediately at the surface of the earth, to be surrounded by Roman cement, to prevent decay.*

An advantage of this plan would be the saving of excavation and embankment on a road for engines, by having the supports rise in some places one or two feet above the surface, and in others be level with it. It would also require less filling in for the path, if the road were intended for horses, than if cross sleepers of wood were used; and the rails would not be jarred by the action of the horses' feet, as they are on the cross sleepers.

It is objected to this plan, that the posts would be liable to spread, so that the rails would vary in their distance from each other. Yet if the rails and rims of the wheels were of

* By John L. Sullivan, Esq.

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considerable width, it would not be likely to take place to an injurious extent, before it could be rectified by the superintendant.

The posts might be prevented from spreading asunder, by iron wires extending across the road from the one to the other; or, they might be surmounted by wooden sleepers stretching across the road, into which the rails might be keyed, in the manner before described. These sleepers might be raised above the earth to any expedient distance, if the road were solely for steam engines.

The wires, or the cross sleepers, need not extend between every pair of posts; but only on those upon which the ends of the wooden rails rest, say once in 12 or 16 feet.

Mr. John L. Sullivan also proposes to use for rails, chestnut timber, *split* from the trees into quarters or eighths, and the part next the heart planed smooth to receive the iron. An advantage of these rails would be, that they will shrink equally in all directions. Where chestnut timber is abundant, and oak scarce, this will doubtless be found a profitable mode.

Expense of Excavation and Embankment.

The amount of this item is extremely various, according to the ground, and still more, perhaps, according to the rate of ascending and descending graduation.

On one mile of the proposed Rail-way from Boston to Providence, the expense, at a graduation of 30 feet to the mile, is estimated at $14,864; which, by a graduation of 50 feet, would be reduced to $2,158; making a saving of nearly 6-7ths by the latter graduation. On another mile a saving of $5000 would be effected, by changing from 30 to 60 feet to the mile.

On the Philadelphia and Columbia Road, at the Mine hill, the excavation on one mile, where the deepest cutting is $35\frac{9}{10}$ feet, will cost about $17,000, at a graduation of $27\frac{1}{2}$ feet. By making the graduation 60 feet the expense would be reduced probably to less than $5000, making a saving of $12,000.

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On the Baltimore and Ohio Road, at two places, the cuttings are about 78 and 79 feet each. By adopting a graduation of 60 feet ascent to the mile, the saving on each of these miles would probably be about $30,000.

An instance of an expensive road may be found in the Baltimore and Ohio Road, where the average expense of graduation for 13 miles is understood to be about 20,000 dollars to 25,000 dollars per mile (exclusive of bridges).

2. A road of moderate expense, is that from Columbia to Philadelphia, where the average expense of excavation and embankment is about 1600 or 1700 dollars per mile for a double track, at a graduation not exceeding 29 feet to the mile.

3. A cheap foundation, made by a graduation of 60 feet in the direction of most transportation, and 80 feet in that of least transportation, might be estimated at 250 dollars per mile for a single, or 500 dollars for a double rail-way. This is above the expense on some parts of the Columbia railway.

Expense of Bridges and Culverts.

This is an item extremely various, according to the number of streams, and the rate of graduation, as requiring high and long, or admitting lower and shorter bridges.

The cost of bridges for the first 13 miles on the Baltimore way, is probably 16,000 to 18,000 dollars per mile.*

The cost on the Philadelphia and Columbia road, between 2500 and 3000 dollars per mile, including the Schuylkill bridge.

The estimated expense of bridges between Boston and Providence, is 530 dollars per mile for a double way: and 315 dollars per mile for a single way. (Hayward's Report.) These are substantial stone bridges.

Perhaps a minimum estimate for bridges and culverts on a road, that avoids streams as much as practicable to advantage, may be in most cases $250 per mile for a single, and

* Bridges and excavations were estimated in the report of the Directors at $37,500 per mile: but have exceeded that sum. I know not the precise proportion which is for bridges.

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$400 for a double rail-way. Mr. W. R. Hopkins, who surveyed the route of 54½ miles from Harrisburg to Chambersburg, estimates the cost for bridges and culverts at 3099 dollars 93 cents for the whole route, being less than 57 dollars per mile, for a double rail-way. There are, however, few places so advantageous.*

Expense of Foundation for the Supports.

It probably would not be advantageous to dispense with the use of broken stone for the foundation of the supports in any case of a rail-way for steam carriages, unless it were that of the substitution of wooden posts, set several feet in the ground.

The broken stone for the foundation of supports at distances of 8 feet, is estimated by Mr. Wm. R. Hopkins, at

For single Road.

182 perches broken stone, at 60 cents,	$109 20

For double Road.

364 perches do.	218 40

And the pit excavation and filling in of the stone, at about $80 for single, or $160 for double way.

Major John Wilson estimates the broken stone for the horse path, and embedding the blocks, at $969 32 for a double way between Philadelphia and Columbia. How much of this is for the horse path is not stated.

The cost of stone will probably be less in many places than on the route of Mr. Hopkins' estimate, viz. that from Harrisburg to Chambersburg.

We may perhaps estimate $150 per mile as the minimum, and $300 as the maximum cost for stone and pit excavation and filling, *for a single track* for steam engines. In many places coarse gravel may be found, which will answer the purpose, and may be had at a slight expense.

Of the Supports and Rails.

The expense of these items, must vary with the abundance of timber, stone, and iron.

The following is Major Wilson's estimate for a road of the best construction of iron and stone.

* Journal Penn. H. R. 1828–9. Vol. 2. p. 475.

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For double Tracks.

Iron rails 28 lbs. per yard; 88 tons per mile, at $65*	$5,720 00
Do. for sidelings,	143 00
Cast iron chairs 18,267 tons, at $45 50,	831 14
Iron pins to fix chairs to rails,	36 00
Duty to the United States on the above, at 25 per cent. ad. val.	1,682 53
	$8,412 67
Blocks of stone, placing them, fixing rails, &c.	1,834 75
Total,	$10,257 42

Mr. N. S. Roberts' estimate is as follows: for rail-way over the Allegheny mountains: double tracks.

4224 stone supports, cut, drilled, and set, at 70 cents each,	$2,956 80
1418 pieces of locust timber 6 by 10 inches square and 15 feet long, at 75 cents,	1,063 50
30 tons iron plates, drilled and delivered at $100* (iron 2 inches by $\frac{1}{2}$ inch).	3,000 00
4 tons of bolts made and delivered at $150,	600 00
One ton spikes, do.	200 00
Total,	$7,820 30

The estimate of Moncure Robinson, Esq. is $9,950 per mile.

For a cheap Track.

A beam of white oak, ash, or pitch pine, 4 inches broad, 7 inches deep, and $3\frac{1}{2}$ feet between the supports, will bear a permanent load of 12 tons without danger of breaking, as we find from Barlow's problems. If the ends be fast, it will bear 50 per cent. more.† As one wheel of the carriage only, will, at one time, rest between the supports, and it will be rare that a weight of two tons will be thrown upon a single wheel of the loeomotive engine, we may take

* Iron is now lower.

† Two-thirds of the pounds required to break a beam according to the problems in page 21, are considered proper for a permanent load.

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the above size of timber, if of the best wood, to be sufficient both for strength and steadiness. It is the size used on the Schuylkill West Branch road. The strength, for the support of carriages, will be materially increased by the iron plates.

The supports may be sleepers or posts. The latter will cost about as much more than the former, as will equal the cost of the greater quantity of excavation and broken stone for the former. So that the expense of the road will be about equal.

For a single Track.

1320 sleepers at 10 cents,	$132 00
Rails 4 by 7 inches white oak, 24,957 feet timber at $12,	299 48
Wedges to fasten rails,	25 00
15 tons iron plates 2 inches by ¼ inch, at $70,	1,005 00
Additional iron by having the plates 3 inches wide on ascents one-tenth of the distance,	58 00
Nails and bolts,	100 00
Workmanship,	112 00
Total for rails and supports, single track,	$1,731 48

SUMMARY.

1. *An expensive double Rail-Way, nearly Level.*

Excavation and embankments per mile,	$25,000
Bridges and culverts,	12,000
Broken stone for supports,	600
Supports and iron rails,	10,400
Total,*	$48,000
Add superintendance and contingencies,	2,000
	$50,000

2. *A moderately expensive or medium road, winding, and having an ascent of 28 feet per mile, double track.*

* The Liverpool and Manchester rail-way is estimated to cost near £20,000, or $93,333 per mile. This includes the purchase of land.

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Excavation, &c. per mile,	$1,700
Bridges and culverts,	2,500
Stone foundation,	500
Stone supports and iron rails, the rails 21 lbs. to the yard,	8,700
	$13,400
Superintendance and contingencies,	1,600
Total,	$15,000

3. *Cheap Road. Single Track. Greatest ascent,* 60 *feet to the mile, one way, and* 75 *to* 80 *feet, the other.*

Excavation and embankment,	300 00
Bridges,* &c.	300 00
Stone for foundation,	150 00
Supports, rails and workmanship, as above,	1,731 48
Superintendance and contingencies,	250 00
Total,	$2831 48

For single track; or $5,672 for double tracks.

CHAP. III.

Of the Carriages for Transportation.

The objects to be attained in the formation of wagons, are, Cheapness, that the capital required may not be great: Lightness, that the greatest practicable portion of the burden may consist of goods: Diminution of friction, that the greatest loads may be drawn by the same power of horses or steam: and facility of turning curves, that neither rails nor wagons may be strained, nor friction much increased at the turns on a crooked way.

In some cases wagons of half the weight of the load are used, which must occasion a great needless expenditure; as the weight of goods carried must be proportionably reduced.

Some of Winan's wagons, recently used on the Liverpool road, weighed less than one-fifth as much as the goods carried, the proportion being 5 to 27. It may well be doubted whether they can be made of so great lightness,

* Very variable.

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and be sufficiently strong and durable. We may hope that a reduction to one-fourth of the weight of the load is practicable.

The strength necessary in the wagons, and the weight of the wheels, depend in some measure on the straightness or crookedness of the road, and on the degree in which the wagons are adapted to turn curves, if the road be crooked. Wherever lateral pressure of the wheels against the rails occurs, the wheels and their axles are subjected to great strain. Such pressure may be in a great measure avoided, by having the outer rail, where the road is curved, raised higher than the inner one.

The rail-road wagons most used, have revolving axles, to which in some cases the wheels are fast. In other cases one or both wheels is left at liberty to slip on the axle, so that where the road winds, one wheel may travel faster than the other to make the curve. Generally however, the axle revolves; this method being better than that of wheels revolving on the axle.

To avoid the friction of the flanges of the wheels against the rails, and to make turns without grinding, Mr. James Wright, of Columbia, Pa. has invented a method, which is supposed to possess peculiar advantages.

It consists in giving a conical form to the rims of the wheels, so that wherever the road curves, the larger part of the rim of the outer wheel comes on the rail, and consequently travels faster than the inner wheel.

Fig. 1. in the annexed cut shows a top view of the wagon frame, and wheels of Mr. Wright's carriage.

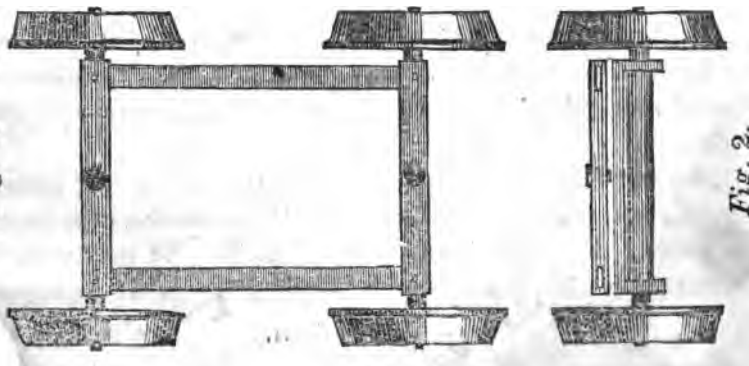

Fig. 1. Fig. 2.

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In order to take advantage of the conical form of the wheels, and have the axle always at right angles to the rails, each axle is fixed to, and revolves in, an under cross piece, which is fastened by a bolt in the middle, to the under side of the wagon frame, as shown in fig. 2. which is a front view of one of the axles and its wheels, together with one of the cross pieces of the wagon frame.

Friction wheels are sometimes put on the ends of the upper, or frame cross pieces, which sustain the weight of the carriage, and allow the axle to vibrate freely.

Mr. Wright's carriage, in models, works very beautifully. A number of wagons on his plan have been ordered at Pottsville. It certainly turns curves with more ease and less friction than any other wagon which has the wheels fast to the axle.

The only objections to this wagon, are, that the wheels operate in a slight degree in the manner of a wedge to press the rails asunder; and that the vibrating cross piece will raise the height of the wagon body a few inches above the axle. The former objection, however, is of less force than that of the side pressure which the flanges of other wagons occasionally produce on the rails, so that the wheels operate as a lever to bend the axle, which must consequently be made larger than in Mr. Wright's plan.

Mr. Wright suggests the use of a round topped rail, although the wagon will work on rails of any kind.

Perhaps if the wagon should come into general use, it would be expedient to have the rails made with a slope at their surfaces, conformable to that of the wheels. One material advantage of Mr. Wright's carriage is, that it will admit of a long body without inconvenience.

William Howard, Esq. of Baltimore, has also patented a wagon for turning curves, and diminishing friction, a description and drawing of which may be seen in the Franklin Journal, for January 1829. It has much ingenuity; but perhaps would be too complicated and expensive for common use.

The chief object in the formation of wagons, is to reduce

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the friction at the axles as low as possible, the friction being, on a level rail-road, the greatest obstacle to locomotion. The simplest mode of effecting this object is to make the wheels as large, and the axles as small as practicable; the amount of power necessary to overcome friction, being inversely as the proportion of the diameter of the wheel to that of the axle; other circumstances being equal. Some have doubted this position; but various experiments by Mr. Palmer, Mr. Tredgold, and lately by Messrs. Hartley and Rastrick, prove its truth.

The wheels generally used on the English Coal rail-roads, for short distances, have been from 32 to 36 inches in diameter, and the axles from $2\frac{3}{4}$ to 3 inches, the wagons carrying loads of $2\frac{1}{2}$ to $2\frac{3}{4}$ tons. The object of low wheels is the greater convenience of loading. But where a rail-road is 20 miles, or upwards, in length, the advantage of diminished friction will far more than compensate for the labour of raising the burthen six inches higher in loading. It will, therefore, be found expedient to increase the size of the wheels to 4 feet diameter, and to reduce the size of the axles to $1\frac{1}{2}$ or 2 inches, diminishing the load of each wagon accordingly, and using a greater number of wagons.

Rail-road wagons have recently been made in England, with axles of $1\frac{1}{2}$ inches in diameter. But perhaps, with wagons of the old form, it will not be advantageous, in most cases, to go below 2 inches. These will bear loads of $1\frac{1}{2}$ tons to a wagon with safety. With such axles, and 4 feet wheels, the friction will be precisely one half that of wheels with 3 inch axles, and 3 feet wheels.

Of the Bearings on the Axles.

Having fixed the size of the wheels and axles, an important inquiry will follow as to the kind of metal to be used for the gudgeons, or chairs, which rest upon the axles at the place of friction; and also what should be the width, or extent of bearing surface, on the axles and gudgeons.

Mr. Wood prefers cast iron for the bearings; but it appears from the experiments of Mr. Rennie, before men-

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tioned, that the friction of wrought iron upon hard brass, without unguents, is one-sixth less than that of wrought iron upon cast iron: and with unguents, the friction of brass on iron is still less in proportion to that of iron on iron.

Brass bearings, or chairs, therefore, should be preferred.

As to the width of the bearings, a material error has been committed, in most wagons, in making them too narrow, thus giving too small an extent of rubbing surface. Friction is not equal for equal weights, on the same axle and bearing surface; but the bearing surface should be proportioned to the weight.

The least friction of brass on wrought iron, was found by Mr. Rennie, to be at 14 lbs. $3\frac{1}{2}$ oz. on the square inch of rubbing surface, at which it took 1 lb. to move $7\frac{9}{10}$ lbs., without unguents; while with 560 lbs. on the inch, 1 lb. moved but $4\frac{1}{4}$ lbs. The least friction of cast iron on wrought iron, was with 12 lbs. 3 oz. on the inch of surface, in which case 1 lb. suspended perpendicularly over a pulley, moved $6\frac{36}{100}$ lbs. over a level plane: but when the weight was 709 lbs. on the inch, each lb. suspended moved but $2\frac{3}{10}$ lbs.: showing an increase in the latter case of more than one half, in friction, compared with weight.

From these results it would appear, that the least friction without oil, would ensue, if the bearing surface of the axles extended entirely across the wagon, say 4 or 5 feet. Yet, the use of oil or other unguents will make some difference in the proper proportion of rubbing surface.

Mr. Wood found, that where oil was used, wagons with iron bearings 4 inches broad, had 38 per cent. less friction than those having bearings only $1\frac{1}{4}$ inches broad.—Wood on Rail-roads, p. 185 to 188.

Of the Unguents to be used.

The amount of friction is materially affected by the nature of the unguents used upon the axles. Thin oil is the best which can be used for light and delicate machinery; but with heavy loads the harder substances are far better.

The following tables, extracted from some of Mr. Ren-

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nie's experiments on friction upon axles, show how greatly the value of different unguents depends on the extent of the load.

Wt. on axle.	Wt. required to move it.		
Brass on iron with oil.			
cwt.	lbs.	oz.	Proportion.
1	3	8	32.
5	29	4	19.14
10	193	8	5.78
Brass on iron, with composition of black lead and hog's lard.			
cwt.	lbs.	oz.	Proportion.
1	7	8	14 93
5	14	8	38.62
10	23	8	47.65
10	20	0	56.00

Wt. on axle.	Wt. required to move it.		
Brass on iron with hog's lard.			
cwt.	lbs.	oz.	Proportion.
1	3	1	36.57
5	47	8	11.78
10	120	8	9.29
Brass on iron with tallow.			
cwt.	lbs.	oz.	Proportion.
1	3	1	36.57
5	13	12	40.72
Brass on iron with soft soap.			
cwt.	lbs.	oz.	Proportion.
1	9	3	12.19
5	14	12	37.96

From these results it appears, that, with *oil*, the friction, in proportion to weight, was near six times greater, when the weight on the axle was 10 cwt., than when 1 cwt.: with hog's lard, the results were analogous: but with black-lead and hog's lard, the effect was reversed, the friction being nearly four times greater, in proportion, with a light load, than with a heavy one. With tallow, also, the heaviest load gave the least friction. Whence we may deduce as a general

RULE:

That for loaded wagons, *hard* unguents are the best.

Tallow is the most uniformly good, with both light and heavy loads.

We are still without a class of experiments, particularly desirable. The abovementioned were made upon bodies in the slowest motion. It would be well to ascertain what unguents most reduce friction, when the travelling is rapid, say 10, 15, or 20 miles per hour, and the axles are consequently heated. Experiments for this purpose might easily be made by the Dynamometer, upon wagons drawn by locomotive engines.

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Pulverized *soap-stone* has lately been discovered, at Lowell, Mass. to afford, in combination with oil, tar or tallow, an excellent application for the rubbing surfaces of machinery; and particularly economical, as one application suffices for many days.* It would be well to try this upon rail-way wagons.

Hard brown soap has been advantageously used to diminish the friction of heavy weights.

Of the amount of Friction.

We have seen in Mr. Rennie's experiments, that by proper unguents, friction, in two cases, was reduced to one forty-seventh, and one fifty-sixth part of the weight: and in another case to less than one-fortieth. In four successive experiments, with tallow, the friction was below the latter rate. In other words 1lb. suspended over a pulley put upwards of 40lbs. in horizontal motion. By proper attention to the kind of unguents to be used, it would seem that we might safely calculate on a general reduction to one-fortieth of the weight. But as dust will be liable to assail the axles, perhaps one-thirtieth would be a safer calculation. This is where the power is applied directly to the weight. But by the wheel and axle we obtain a leverage, by which the power required to overcome friction is reduced in proportion to the diameter of the axle, compared with that of the wheel. Multiplying 30, by the diameter of the wheel, and dividing the product by that of the axle, we obtain the friction of wagons.

Hence we find that friction on the axles would be as follows:†

Axles 3	inches.	Wheels 36	inches.	Friction	1lb.	in	360lbs.
Axles 3	"	Wheels 48	"	"	1	"	480 "
Axles 2	"	Wheels 36	"	"	1	"	540 "
Axles 2	"	Wheels 48	"	"	1	"	720 "
Axles 1	"	Wheels 60	"	"	1	"	1800 "

* A large heavy wheel at the iron works on the mill dam at Boston, with gudgeons 5 inches in diameter, making 75 to 100 revolutions per minute, has run with soap stone, for 5 weeks, without renewing the lubrication.—*Franklin Journal for April* 1830, p. 275.

† With tallow. The friction with oil would be greater.

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This is the friction upon the axles, occasioned by the load resting upon them, the weight of the wheels not being taken into the account, as it does not rest on the axles. To this result is to be added, the friction of the rims of the wheels upon the rails. This is of two kinds, the rolling friction on the surface of the rail, and the rubbing friction of the flange pressing against the side of the rail.

What is called rolling friction is of little moment, if the rails are smooth and clean. Theoretically it is nothing, for a perfectly round ball will roll over a perfectly smooth and level plane, without any friction. Yet neither a perfect ball or wheel, nor a perfect plane can be obtained. All particles of dust will interrupt the evenness of the plane, and create friction. Hence the importance of having the rails constantly swept by brushes attached to the forward wagon of each train.* Mr. Henry Palmer, of Cheltenham, England, found the resistance on a plate rail, when the rails were dusty, one-fifth more than when they were swept clean. The difference, however, would be much less on the edge rail. The larger the wheels, the less will any dust, twigs, or inequalities on the rails affect them. On the whole, the rolling friction on a rail-way, kept in good order, and the wagons having large wheels, is almost too small to take into account.

The friction of the flanges of the wheels against the sides of the rails is of more moment, especially if the rail-way be winding, and the wagons of the usual construction. If the road be straight, or if Mr. Wright's carriage wheels be used, this item also will be reduced to a very trifle. I know of no experiments to ascertain its amount, which indeed must vary with every road, and on every mile of the same road.

We have, however, experiments showing the sum total of friction in wagons of a certain construction.

* This is particularly important before a rain, as the mud produced in such case from the dust, is very detrimental.

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Wheels 35 inches in diameter, Axles 3 inches do. Bearings 4 do. broad, of cast iron,	On Hetton Rail-Road.

Average friction in five different experiments 1 lb. to 211½ lbs. of weight of wagon and load.

The experiments on the Killingworth Colliery were a little less favourable; but as it was a rail-road of old construction, and not in good order, the Hetton affords the fairest test.

The wagons were *oiled* in these experiments. The loads being heavy, tallow would have shown much less friction.

In the above experiments, the proportion of wheels to axles, was as 11.6 to 1. We have proposed to make it as 24 is to 1.—This should reduce the friction to 1 lb. in 422.

which make, friction $\frac{1}{422}$ of the weight

Recent experiments at Liverpool have shown, that where the axles are in the latter proportion, the friction is but 1 lb. in 400.—The substitution of proper unguents instead of oil, will, doubtless, reduce the friction yet lower.

Of Friction compared with Velocity.

It is important to know what is the friction of carriages, at different velocities, in order that we may ascertain if there be any loss of power by travelling fast. With steam boats, canal boats, and other vessels moving through the water, it is known that the resistance is greatly increased in travelling fast, and therefore the slower the motion the greater the economy in the power expended.

Two modes have been used to test both the actual amount of friction on rail-roads, and its proportion to the velocity of motion.

One of these methods is to let wagons move down an inclined plane by their own gravity. It is known that they would, if there were no friction, descend with a rapidity having the same proportion to that of a body falling perpendicularly, as the height of the plane has to its length; and that this velocity would be equally accelerated during every second of its descent. By comparing the velocity of the wagon at starting, with that which it would have, if there

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were no friction, we ascertain the amount of friction compared with weight; and by comparing the velocity in different equal portions of time, we ascertain whether it is regularly increased, or whether its increase is checked by an increase of friction.

By this method it was found that friction was equal at all velocities; the wagons, in various experiments, (Wood on Rail-Roads, pp. 199–201) were equally accelerated in equal times, till they reached the foot of the inclined plane.

Another mode of trying the experiment is by the dynamometer, consisting of a pendulum, suspended from a cross-bar. See plate 1, fig. 2. It is first ascertained to what extent different weights suspended over a pulley will remove the pendulum from the perpendicular, allowance being made for the friction of the pulley.

Then the wagons being attached to the line, they are drawn along by moving the cross-bar at the top, or the carriage in which it is fixed, and when the motion is regular, the number of degrees that the weight or pendulum is removed from the perpendicular are noted, and the friction of the wagon is considered as equal to the weight which would have removed the pendulum to the same extent. By moving at different velocities, it is ascertained whether friction is increased. The result of various experiments, by Mr. Wood, was, that the friction was the same, at a velocity of 104 feet, 307 feet, and 397 feet per minute.

Another mode of ascertaining whether friction is increased by velocity, is, to suspend two weights over a pulley or wheel and axle of any kind, the one being just enough heavier than the other to counterbalance the friction. When these weights are put in motion, the motion will be uniform. If they are started with a slow motion, they will continue at the same; if a rapid motion is given, they will continue to move with the same rapidity.*

All these results show that the constant stress or pressure required to overcome friction, is no greater at high velocities, than with the slowest motion.

* Rennie's Experiments, Franklin Journal, for February, 1830.

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From this fact, some have inferred, that there would be an actual gain of power in travelling with rapidity; because the pressure or stress, from friction, is equal in equal times; from which it might seem better to travel 10 miles in half an hour, than in a whole hour, as the stress or pressure would be equal in each case, but would continue twice as long in the latter.

The established principles of mechanics show, however, that the power expended in the two cases is equal; at least if it be measured by the effect of steam; and that the real expenditure to overcome friction is in proportion to the distance travelled, without any regard to velocity.

There is a small saving, by travelling slow, with a heavier load, because the steam carriage must be moved over the ground a fewer number of times, to transport the same quantity of goods.

Proposed Improvements in Wagons.

From what has been observed, the immense importance will be seen of overcoming friction, by having the distance which the rubbing surface on the axle traverses, as small as possible, compared with the distance passed over by the wagon.

For the purpose of effecting this object, Mr. Ross Winans of New Jersey, a Mr. Knight, and William Howard of Baltimore, have invented carriages upon similar principles. Mr. Winans is supposed to be the first inventor, although his invention was unknown to Mr. Howard.

Mr. Winans' carriage is provided with 4 friction wheels having short axles fixed into a frame, similar to that of plate 2, fig. 8. The whole load rests on the axles of the friction wheels. These wheels have a projecting rim on the inner side of their circumference, under the edge of which the ends of the axles of the larger wheels, (that run on the rail)s, are admitted, so that the friction wheels hang on the main axles, and the load on the friction wheels.

Plate 1. fig. 4. represents the carriage of Mr. Winans:

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f. f. are the friction wheels: and *m. m.* the main wheels running on the rails, which is represented in the plate as raised above the ground.

As the main axles move round, the friction wheels move with them, so that the axles of the friction wheels, where the rubbing takes place, move but once round to several revolutions of the main wheels.

The friction of some of Mr. Winans' wagons on the Liverpool and Manchester road, has been found to be but 1lb. in about 800. It is doubted by some, however, whether they will ever come into extensive use, by reason of their complication, and the liability, as heretofore constructed, to get out of order.

The author of this work has devised a wagon, for which he contemplates taking a patent. It is hoped it will reduce friction as low as 1lb. in a 1000, on a straight road, without the inconvenience of numerous wheels, or a high load.

Plate 2. fig. 8. represents a *top* view of the frame and wheels of this wagon. The frame consists of four longitudinal and two lateral pieces of timber, which must be of sufficient size to give the requisite strength and steadiness. Each wheel has a short axle, which may be four or six inches in length, running in iron bearings, on the under sides of two of the timbers of the frame, so that the load will rest upon both ends of each short axle, the whole number of bearings being eight, or two to each axle. The wheels are to be conical on their rims and flanges, to prevent the rubbing of the flanges against the rail, and the running off of the wagon, as well as strain to the axles: there being lateral room for a play of 1 inch between the rails and the flanges. The body of the wagon, which is not shown in the drawing, is to be suspended from the wooden frame, in such manner that the weight will bear equally on each end of the four axles.

The supposed advantages of this wagon, are—1. That the wheels may be of any width not exceeding five or six feet, without danger of running off.—2. That the axles by having bearings on each side, and near to, the wheels, will

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require to be of but one half the strength of those in the ordinary method: axles of 1 inch in diameter in this wagon, being of strength sufficient to carry weights of 1½ tons, beside the carriage.—3. That as each wheel has a separate axle, the wheels may be fast, and the axles revolve, without inconvenience on curved roads.—4. That the body of the wagon may be hung entirely below the axles, or at any higher point, at the will of the maker, without encountering any inconvenience, such as would result if the axles extended across from one wheel to the other. Of course the wheels may be as high, and the body at the same time as low, as may be wished. This is the principal object of this mode of construction.

If the wheels be 5 feet, and the axles 1 inch in diameter, and tallow be used on the axles, the resistance by friction on them cannot amount to more than one twelve-hundredth part of the weight, and will probably be considerably less.

If this plan should not prove advantageous, some method will doubtless be devised for using high wheels, without raising the load, such as cranking the axles, or allowing them to pass through the body of the wagon: for it is only by having large wheels in proportion to the axles, that railways can be brought to the perfection of utility.

The wagons used on the English roads, have cast iron wheels, with wrought iron spokes, the ends of the spokes being dovetail shaped, so that the cast iron firmly adheres at the nave or hub, as well as at the felloe. The rims are generally case hardened by running against a cold iron cylinder, which prevents their wearing into grooves. If wooden wheels could be substituted, with tire of suitable form, it would be an improvement, as they would weigh less than iron in proportion to their strength.*

* Since this work was put to press, the author has seen the specification and drawings of a rail-road car, invented by Mr. S. T. Jones of Philadelphia. *See Franklin Journal, for March* 1830. Mr. Jones proposes to use but two wheels to each car, to be supported on short axles in the manner above named, or on long axles extending through the body of the car: the body being suspended below

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Of Checking undue Velocity.

Before leaving the subject of wagons, it is proper to mention the mode of preventing them from acquiring an undue velocity where the descent is of considerable steepness. This is done by means of what is called a "*brake*" or "*convoy*," so placed as to press against both the fore and hind wheels.

Plate 1. fig. 1. represents the form of wagons used for coal in England, with the brake attached. *a. b.* is the jointed brake fastened to the side of the wagon body in such manner as to press on both wheels. By this means it is found very easy to regulate the speed, as there may be different places to hitch the upper end of the brake to the wagon body, to make it press with more or less force.

Mr. Morris, an ingenious mechanic, who has planned the best inclined planes on the Morris Canal, has devised what is termed a *governor* to press upon the wheels of the frames which support the boats, whenever they move too fast, the motion of the carriage regulating the application of the governor.

It is probable, a similar appendage might be attached to the last wagon of each train, on rail-roads, so that no care would be required on the part of the attendant.

Expense of Wagons.

The cost of rail-way wagons used at Pottsville, varies from 40 to 70 dollars. These carry 1½ ton each. It is probable that the improved wagons which will be used ultimately, will cost about 50 dollars to each ton of goods, or 75 dollars for a wagon to carry 1½ tons.

Rail-road cars have been in use on the Killingworth Road, Eng. for 11 or 12 years, and are still good. It probably would not be unreasonable to estimate the cost of renewals

the axles. The cars are to be connected when travelling by short tongues, or projections, and a bolt, so that each car may have a different angle on a winding road. The objects are to have the wheels high and the load low, and to turn curves with facility. The plan appears to be a very good one.

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and repairs at 12 per cent. per annum, which added to the interest, would make the yearly expense per ton, 9 dollars.

CHAP. IV.

Of Locomotive Engines.

We shall first describe the different kinds of locomotive carriages that have been used, and then consider the objects which are desirable in relation to them, and the mode of their attainment.

The first steam carriage for rail-roads was made by Mr. Trevithick in 1804, and tried on the Merthyr-Tydvill Rail-road in South Wales. We have not a particular description of this engine, except that it had an eight inch cylinder for the piston, and the piston had a 54 inch stroke. It drew after it as many carriages as contained ten tons of bar iron a distance of nine miles, at the rate of five miles an hour.

The supposed want of sufficient adhesion of the wheels to the rails, prevented any considerable use of locomotive engines, till 1811—when Mr. Blenkinsop of Middleton Colliery, near Leeds, obtained a patent for the application of a rack or toothed rail, into which wheels turned by the engine worked, and thus moved the carriage.

Plate 1, fig. 3, represents Mr. Blenkinsop's engine, and the rack-rail. The plate will explain the form of this engine. It has two cylinders A. B. the motion from each piston being communicated to the large cog wheel, through the rods *c c.* and *d d.* and the two small cog wheels with which they are connected. The cogs on the rail, consist of semi-circular protuberances, projecting horizontally 2 or 3 inches from the outer side of the rail. This kind of rail is used only on one side of the road, the other rail being of the usual kind. The boiler is cylindrical, heated by a circular tube passing through it.

Engines of this kind were put in operation in 1811 or 1812, on the rail road from Middleton to Leeds, and have

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been used ever since. One of them is said to convey 27 wagons, carrying 90 tons of coal.

Mr. Blackett of the Wylam Colliery, was the first individual who established the practicability of effecting motion with sufficient loads, by the adhesion of the engine wheels to the rails. This was in 1813. His engine had but one cylinder and piston, which was found disadvantageous; as, notwithstanding the use of a fly wheel, the motion was irregular. And whenever the engine happened to stop, with the piston at the top or bottom of its stroke, it could not be put in motion till it had been moved by manual power, so as to give leverage to the action of the piston rod. Two cylinders have, therefore, been usually chosen, the rods from the pistons being attached in such manner that when one is at its dead point (that is, at the top or bottom of its stroke), the other shall be at the middle of its stroke, and point of greatest power. This combination renders a balance or fly wheel unnecessary.

The principal improvements in locomotive engines prior to the year 1829, were made by Mr. George Stephenson* who was engaged at the Killingworth Colliery Rail-road. In 1815, he, in conjunction with Mr. Dodd, took a patent for applying the motion directly to the wheels of the engine by attaching the piston rods to one spoke in each wheel, avoiding the use of cog wheels through which the motion had before been transmitted to the axles. And in 1816, Mr. Stephenson, in conjunction with Mr. Losh, took a patent for supporting the weight of the boiler and engine, or a part of it, by pistons extending into the boiler at or near its bottom, and resting on the axles, the escape of the steam being prevented by packing. The elasticity of the steam in the boiler, resting on the tops of these pistons, tends to raise the boiler up, and gives it a spring, so that the weight is divided equally upon the axles, in case of irregularity in the motion of the carriage, produced by unevenness in the rails.

* I believe the present engineer on the Liverpool and Manchester Rail-way.

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Plate 1, fig. 6, represents one of these engines, with the omission of some subordinate parts, not necessary to its elucidation.

In the plate, one side of the boiler is supposed to be removed, so that its interior, and the pistons that partly support the boiler are seen. The boiler is at liberty to move up and down, so that it may spring when the carriage is jolted.

The endless chain extending between the wheels, serves to transmit the motion from the one wheel to the other, so as to avoid the necessity of a fly wheel, and it keeps the wheels in such position that when one piston is at the top or bottom, the other will be at the middle of its stroke.

If it were wished to obtain the advantage of the adhesion of six wheels to the rail, to aid in ascending acclivities, toothed wheels may be attached to the middle wheels of the carriage and the chain passing over them, they must necessarily move with the other wheels.

The late offer of a prize of £500 for the best engine, by the Directors of the Liverpool and Manchester Rail-way, produced three engines of superior excellence, which we shall proceed to describe.

1. THE ROCKET.

This engine, which obtained the prize, was made by Robert Stephenson of New Castle.*

Annexed is an external elevation of the Rocket and its tender, on a scale of a quarter of an inch to a foot.

The furnace A. is two feet wide by six feet high: the boiler B. is 6 feet long and 3 feet in diameter. The furnace has an external casing, between which and the fire plate there is a space of 3 inches filled with water and communicating with the boiler. The heated air is circulated through the boiler by means of twenty-five copper pipes of three inches each in diameter, which have their termination in the tall chimney, C. FG are safety valves; HH the steam eduction pipe. D, one of two steam cylinders which

* Said to be the son of George Stephenson before mentioned.

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have an angular inclination towards the wheels, and embrace like two arms the boiler between them. E, one of the connecting rods which give motion to the wheels; *a*, the slide of the piston of the cylinder seen in the engraving; and *o*, one of the two escape-pipes. M, is the part of the tender appropriated to the carriage of fuel; N the water-cask.

The weight of this engine with its compliment of water, is 4 tons 5 cwt.

The following is a description of some of the performances of the Rocket.

On the first day it ran at the rate of 15 miles an hour, with a load of 13 tons, beside the engine.

On the third day it went 70 miles with three times its weight, at a rate of upwards of 11 miles an hour, including stoppages. At one time it performed 13 miles within the hour.

On the fifth day, without a load, it went seven miles in 14 minutes, or 30 miles an hour.

On the 8th day, it several times ascended the inclined plane at Rainhill, which rises 1 foot in 96, or 55 feet to the mile, with heavy loads of passengers, at the rate of 12 miles an hour.

Subsequently its performances were still greater.

A load of 33 tons was attached to the carriage which it drew several miles at 13½ miles an hour. An additional load was then put on, which raised it to 37½ tons, and with this it proceeded at the rate of 13¾ miles an hour, its speed constantly increasing as it got into practice. The load was then raised to 42 tons, or ten times the weight of the engine, and with this it proceeded at the average rate of 14 miles an hour.

Another class of experiments was afterwards tried to ascertain with what load, and at what rate it would ascend the inclined plane at Sutton, when it was found that with 11 tons it travelled the 1½ mile in 5 minutes and 35 seconds, or 16 miles an hour; and with 16 tons in 7 minutes 10 seconds, or 12½ miles an hour.

The Directors of the Railway ordered four more engines

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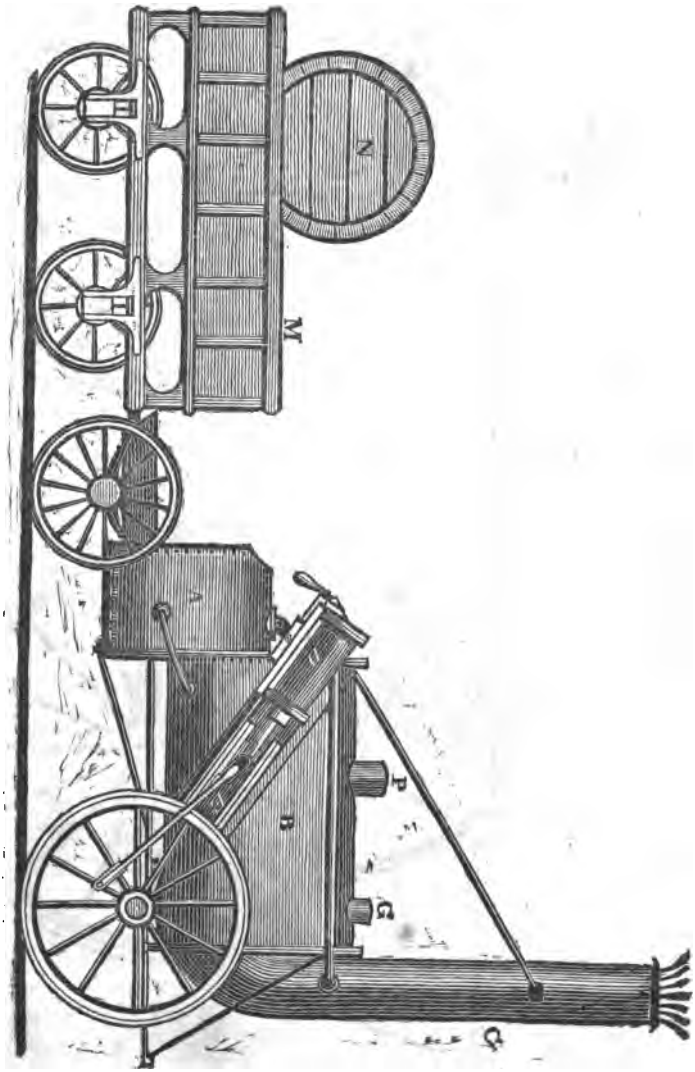
THE ROCKET.



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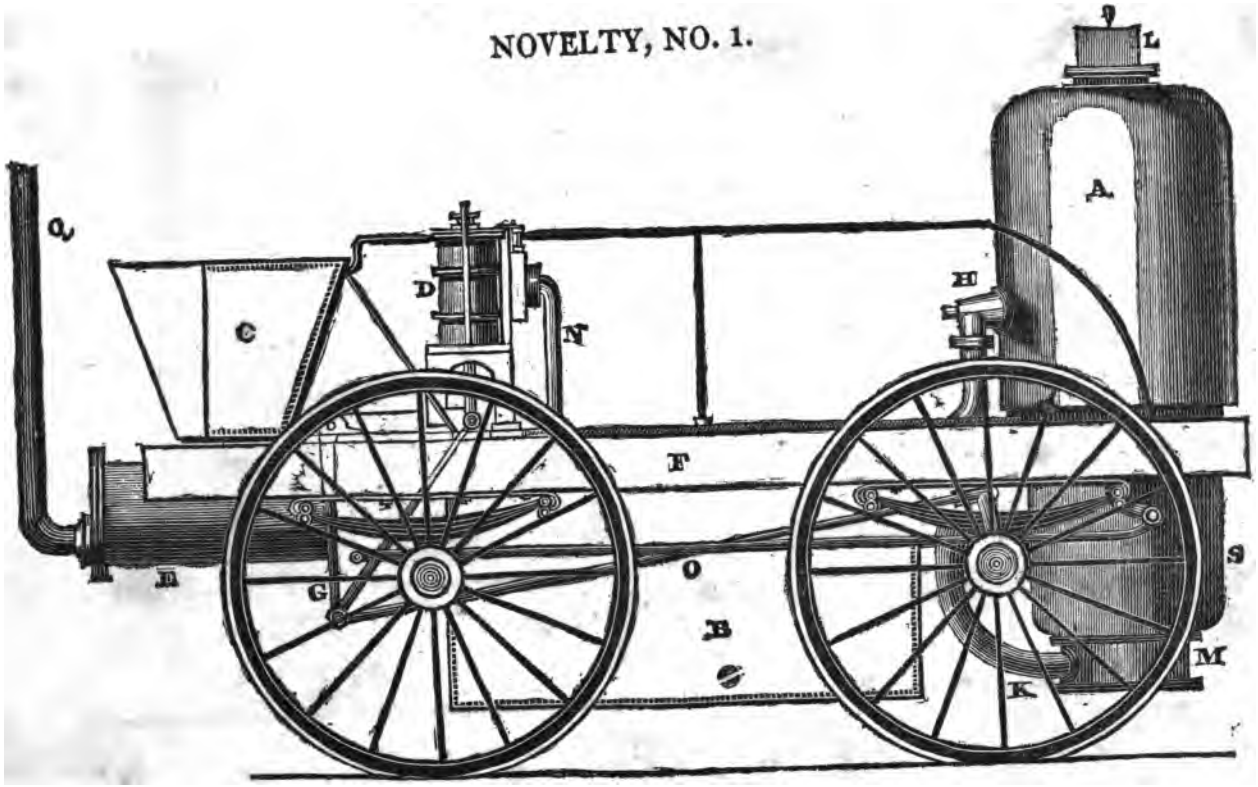
NOVELTY, NO. 1.



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on the same principle as the Rocket, one of which, the *Wildfire*, has been completed. It has larger wheels, cylinders, and pistons, than the Rocket, and is said to exceed it in power.

The Novelty.

This Engine, made by Braithwaite and Errickssson, of London, is on an entirely new plan, affording great lightness; its whole weight being 2 tons 15 cwt. without water or fuel; or with water and fuel, in the boiler and furnace, 3 tons.

The prefixed engraving, No. 1, exhibits the external elevation of the engine. F is the carriage-frame; E the end of a circular boiler which passes under the carriage-frame towards the steam chamber A; L a hopper to receive the fuel, (which is carried in two small baskets placed on the frame). whence it falls though a pipe in the centre of the steam chamber A, into the furnace S; M the ash pit; D and N two working cylinders and their slides (one of each only is seen in the engraving); B the water-tank; C an air-compressing apparatus, which acts on the furnace through the medium of a pipe that passes under the frame-work, and ends at K; N a pipe for the escape of the heated air; O G the connecting rods which impart the action of the pistons to the wheels.

The boiler is made to contain about 45 gallons of water; the diameter of each of the cylinders is 6 inches, and the length of the stroke 12.

The engraving, No. 2, is intended to explain more particularly a very beautiful arrangement of the springs, to which this engine is mainly indebted for its superior steadiness when in action. The axle-trees, being cranked, are fixed to the iron rod A, and a sling, C is introduced to obviate that side action which would otherwise take place between the rod and the carriage-frame B. Again, to prevent the action of the springs from interfering with the action of the engine, the connecting rod, D, is placed as nearly in a horizontal position as possible; the connecting rods are moved by bell-cranks, E, which are connected by slings, F, with the piston rod.

The wheels are of the excellent description patented by Messrs. Jones & Co., and the choice of them by Messrs. Braithwaite and Errickssson is as strong a tribute as could well have been paid to their merits. From the peculiar manner of their construction, they act with the least possible interference from the weight of the engine, and being perfectly cylindrical, bear equally with their whole breadth on the rails. The lightness for which these wheels are famed, is not in this instance so remarkable, "The Novelty" being itself in its

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main parts so light, as to throw other things in comparison with it into the shade. Of the total weight of 2 tons 15 cwt., we believe 18 cwt. falls to the share of the wheels.

S is the furnace, which is supplied with fuel from the hopper L (see the annexed engraving, No. 3,) through the vertical tube in the centre of the steam-chamber A; the heated air from this furnace passes off through a flue, which is made to wind twice or thrice up and down the cylinder EE, and gradually diminishes in diameter till its termination in the escape-pipe Q. The parts shaded in the sketch are those occupied by the water, which, it will be observed, surrounds the boiler as well as the flue.

The extent of surface exposed to the action of the heat by this arrangement, is a great deal less than in other engines; and were the heat left to circulate as in other engines, through the agency of what is commonly called atmospheric draught merely, there would probably be nothing gained in respect of the quantity of steam generated. But instead of depending on the atmospheric draught, Messrs. Braithwaite and Errickssson make use of the bellows-sort of apparatus (CK) in No. 1, to force the heated air through the flue; and by thus supplying a greater quantity of caloric in a given time, they obtain an effect precisely analogous to what would result from doubling or quadrupling the size of the furnace and the extent of the flue.

The flue is made to diminish *gradually*, because the heated air cools in its passage through it, and gradually requires less and less vent. It has also a downward inclination given to it, as represented in the sketch—such, that if a marble ball were dropped in at the furnace end, it would roll rapidly through all the convolutions of the pipe to the other extremity; and the object of so constructing it, is, that any dust which may arise from the furnace may have always a descending passage to escape by.

In the specification of the patent which Messrs. Braithwaite and Errickssson have taken out for this mode of generating steam, mention is made of two air-forcing pipes: one by which atmospheric air is forced on to the *top* of the fuel in the furnace; and another through which the air is forced under the bottom of the fuel. A double supply of air, however, is only considered necessary where coal is the fuel employed, in order to insure its combustion more effectually; and where fuel of the purity of coke is made use of, as in "The Novelty," the upper pipe is dispensed with.

There are, of course, cocks to regulate the transmission of air through the pipe K; also safety-valves to the boiler and steam-chamber; but these, as well as the feed-pump for supplying the water from the tank, have been left out in our sketches, as being unnecessary to illustrate the principle of the engine.

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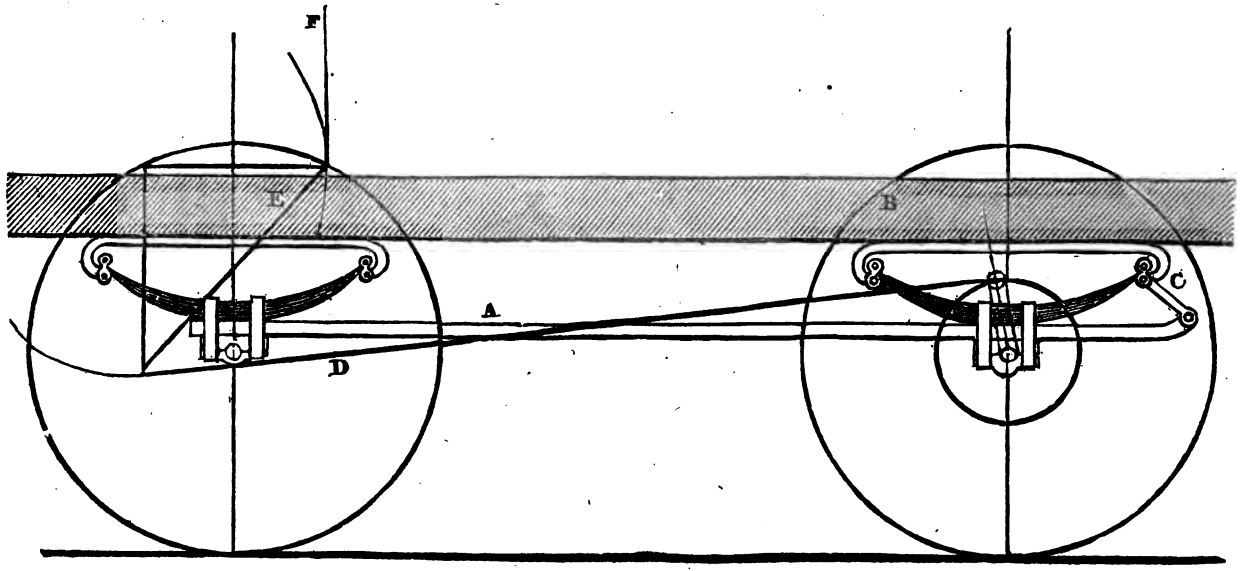
NOVELTY, No. 2.



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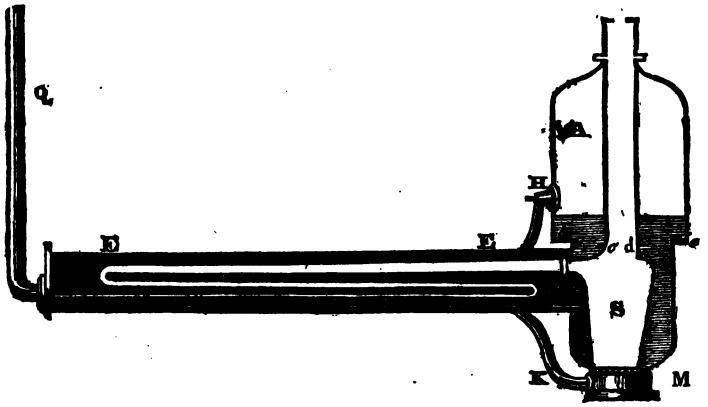
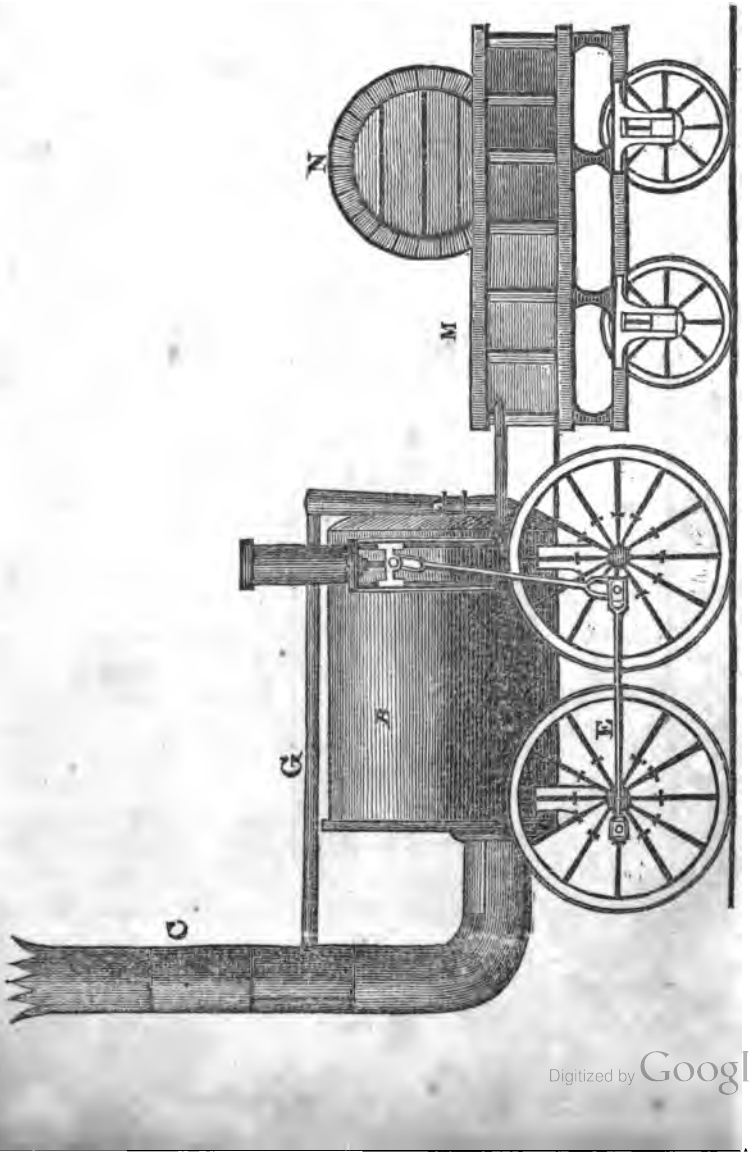
NOVELTY, No. 3.



THE SANS PAREIL.



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Performance.

The Novelty sometimes, with light loads, ran at the rate of 30 miles an hour.

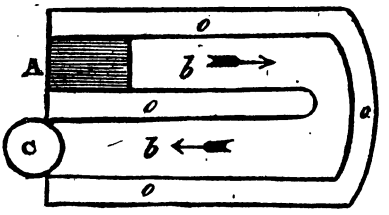
With three times its weight, it went at an average rate exceeding 16 miles an hour, when under way, and a part of the distance at about 20 miles an hour.

With Winans' wagons, it drew 32 tons, or upwards of 10 times its weight, at 13 miles an hour; and with Stephenson's wagons it drew 23 tons at the same rate.

It does not appear to have succeeded in long journies with heavy loads so well as the Rocket. Yet its simple arrangement, its lightness, and steadiness, excited general admiration.

THE SANS PAREIL.—*By Mr. Ackworth, of Darlington.*

The preceding engraving presents an external view of this engine and its tender, on the same scale as the "Rocket," namely, a quarter of an inch to a foot. It exhibits in its general appearance—particularly in its large dimensions—a near resemblance to Mr. Stephenson's engine; but is much more compactly arranged, and on account of this compactness, travels with much greater steadiness. The furnace and boiler are not placed head and tail-wise, as in "The Rocket," but form together the main body (B) of the engine, being constructed in the manner represented in the following diagram:—



A is the furnace, *bb* the flue or tube through which the heated air passes in the direction marked by the arrows, to the chimney C. The boiler (*oooo*) surrounds the furnace and flue. The working-cylinder D, and connecting-rod E, &c., are similar to those of "The Rocket," with the exception of being vertical instead of horizontal. The waste stream passes into an external pipe G, which has an ascending direction given to it towards the chimney C; so that whatever portion of it is there condensed may fall back through the vertical branch-pipe at its lower extremity into the feed-pumps (one of which is only represented in the drawing.)

The weight of the Sans Pareil is 4 tons, 8 cwt. 3 qrs.

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Performance.

For a distance of 25 miles, the Sans Pareil travelled 14 miles an hour with three times her weight. One of the forcing pumps for the supply of the boiler was out of order, which prevented her continuing the distance of 70 miles, fixed on for the competition.

The engine was purchased of Mr. Ackworth, by the Directors of the Railway.

Of Desiderata in Locomotive Engines.

It is important to make engines for locomotion *as light as possible*, in proportion to the power, in order that they may draw the greater load in proportion to their own weight.

This is to be effected chiefly by having the greatest possible quantity of surface exposed to the heat, with a given sized boiler and weight of water, so that steam may be produced with great rapidity. The plan of having a great number of cylindrical tubes pass through the boiler, after the manner of that of the Rocket, invented by Mr. Booth, is very advantageous.

Suppose a single tube or flue of 20 inches diameter, passed through the boiler, the surface exposed would be 60 square inches to each inch in length. The 25 copper tubes of 3 inches diameter, occupy no more space than this one large tube would. But the 25 tubes expose 9 inches of surface each, making 225 inches in all to each inch in length, showing an advantage of nearly 4 to 1, by using the small tubes.

Again, if the tubes were $1\frac{1}{2}$ inches only in diameter, and their number 50, they would occupy no more space than at present, but the surface exposed would be $4\frac{1}{2}$ inches to each tube, or 450 inches in all, making an advantage of more than 7 to 1 in favour of the small tubes, compared with one large one.

All the small tubes will weigh no more than the one large one; for the thickness necessary to secure the proper strength, is precisely in proportion to the diameter. If one

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inch thickness is required for the large tube, one-twentieth of an inch is sufficient for the small one.

An additional advantage of the small tubes is, that being much thinner, they will convey the heat to the water much faster, in proportion to the surface exposed, than a thick tube.

There is a like saving in the weight of the boiler. The strength requisite in the boiler to prevent its separation or bursting, is in proportion to its diameter; for the pressure at any point tending to rupture it, is in proportion to the sum total of all the pressures on one side of it.

By reducing the boiler one half in diameter, we may reduce it one half in thickness, making a reduction of three-fourths in the weight.

Take a boiler of three feet in diameter with a single tube of 18 inches; required to know the comparative weight of a boiler, having small tubes of 2 inches in diameter, to expose the same surface as that with the large tube.

The large tube exposes 54 inches: the small ones will expose 6 inches each. Nine of them will therefore be required. These will occupy a space of six inches square. Twelve inches diameter will therefore answer for the boiler. The boiler must consequently be one-third as thick as the other; and being but one-third as large, it will weigh only one-ninth as much.

Hence we see the advantage of a boiler like that of the Novelty, in being long and narrow. The defect in the Novelty's is, that instead of one tube, it should have four or six, going but once or twice through the length of the boiler.

Another mode of saving, in weight, is to produce an *intense heat;* as the radiation to the water in that case will be greater on each inch of surface. The bellows adopted in the Novelty, will effect this object.

The working with high steam will also assist in the reduction of weight. An intense heat will enable the use of high steam: and if boilers of small diameter are used, the strain will be less than that of low steam in larger boilers.

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Working the engine with great velocity will also aid in a reduction of weight in the cylinders and pistons, as they will expend more steam and do more work in a given time, by moving fast than slow, without any loss of power, if within reasonable limits.

A reduction in the size of the steam chamber, as well as in the quantity of water carried, will farther serve the same purpose. The objection made to this course, is, that the pumping in of fresh water, will cool the boiler, and the steam, too fast, if there be not a large quantity of steam in the boiler. This difficulty, occurring in the ordinary mode, will be in a great measure obviated by the use of the bellows, to produce a sudden and powerful heat, as well as by having the water to be used, previously heated, by condensing the steam in it, after it leaves the boiler. By the latter process the water may be nearly at the boiling point, when pumped into the boiler.*

In locomotive engines, the time may be chosen to pump in water, when the descent of a declivity is commenced, and the engine will need little or no steam to urge it forward. By the time it commences an ascent, the steam, with the aid of the bellows, will have got sufficiently high.

Economy of Fuel and Steam.

Perhaps the most obvious mode of saving fuel is by working with as high steam, as is practicable and safe.

It is well established, that a pound of steam, under high pressure, contains no more heat than a pound under low pressure. (Henry's Chemistry, Art. Caloric, p. 149.) It is true, the high steam *appears* hotter, and will affect the thermometer more, but this is because it is compressed into smaller bulk, and has less latent, but more active heat.

The following table will represent nearly the proportionate power of a given weight of steam under different pressures, in addition to that of the common atmosphere.

* The engine used at the mint in Philadelphia, has the steam, after it has done its work, pass through several tubes, which tubes pass through the water intended for use. Thus the water is kept at the boiling point.

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				Power.				
Under	1	atmosphere or	15lbs.	per inch.	1	heat	250	degrees.
"	3		45 "	"	2	"	293	"
"	7		105 "	"	3	"	343	"
"	15		225 "	"	4	"	400	supposed.

Whence we find the power increase in so small a ratio to the increase of pressure, after we reach 105lbs. to the inch, that it is not an object to incur the increased strength and weight of boiler, and increased danger from working at a higher rate. The common high pressure engines have usually 150lbs. on the safety valve, but probably work with steam at about 100lbs. They are, therefore, nearly right. It might be more prudent to reduce the weight on the valve to 125lbs.

In order to render high steam profitable, it must be cut off short of the full stroke. For if the cylinder full of steam at the same density as that in the boiler be allowed to escape at every stroke, the high steam, working against a vacuum, would do no more work in proportion to its weight and heat, than the low steam. A cylinder full at 105lbs. pressure, would do seven times the work, or move seven times the load of a cylinder full at a pressure of 15lbs.; but it would have seven times the density and seven times the quantity of water. The only saving by high steam, *working at full stroke*, results from the less proportion which the resistance of the atmosphere bears to the power of the high steam than to that of the low.

Tredgold estimates the proper place for cutting off the steam to be $\frac{1}{2}$ stroke for steam of 3 atmospheres, or 44$\frac{1}{2}$lbs. to the inch: and $\frac{3}{8}$ stroke for steam under a pressure of 7 atmospheres, or 104lbs. to the inch. This is not to cut it off so soon as theory would dictate. The above rates are probably correct, estimating the steam by the pressure on the safety valve, but engines are rarely worked under a pressure very near the weight on the valve. If it be actually worked at 104 lbs., the steam should be cut off at quarter stroke. A gain of above 50 per cent. in power

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is obtained by cutting it off thus, instead of allowing it to escape during the whole stroke of the piston.*

Where there is but one cylinder and piston to an engine, inconveniences may result from cutting off the steam so soon: but with two cylinders, as used on rail-ways, no evil results, for when the steam in one cylinder is weakest, that in the other is strongest, and an equilibrium is preserved.

Another mode of saving fuel, is to have the furnace so constructed, and the fire so made, that no air can pass into and through the flue, without a perfect combustion of its oxygen. This is attainable by having the coal fill the furnace completely, to a considerable depth, and the air forced through it by a bellows, as in the Novelty. Suppose double the quantity of air which is necessary passes into the flue, then that which has not its oxygen consumed, mixes with the other, and reduces the temperature one half: nearly double the size and extent of tubes or flues are necessary to convey it away; and thus the weight of the engine is increased.† And when the air leaves the flue, it will convey away heat unnecessarily. It must pass away at a heat above that of the water, at the end of the flue. Suppose it to pass away at a heat of 160°, while the atmos-

* Tredgold on Rail-roads, &c. p. 161.—It is probable Tredgold made his calculations from actual experiment. This, if the engine was worked as many are, would lead to error. In many cases the induction pipe by which the steam enters the cylinder is so small, or is so far closed by the throttle valve, that the steam in the cylinder when the stroke is cut off, is of much less density than that in the boiler. The advantage of the high steam is therefore, in a great measure, lost. The passage into the cylinder should be of the same size with the piston, and the stroke cut off at such place as would give the proper power.

† Sir Isaac Newton calculated that the proportion of heat which a body lost in one minute, was 9-10ths of what it possessed above the surrounding medium. Thus, if the heated air passes into the tube at a heat of 1000 degrees above the water of the boiler, it will lose in one minute 900 degrees: but if the air enters at a heat of 500 above the water, it will lose in the minute but 450 degrees, so that if unconsumed air be mixed with the consumed, in equal quantity, precisely double the extent of surface of tubes will be necessary to abstract the same quantity of heat in the same time. Hence the advantage of an intense heat, which the anthracite coal is far better adapted to produce than the bituminous.

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phere is at 60°; if double the necessary quantity of air passes out, 100° of heat in the additional quantity of air, will be unnecessarily wasted.

A further mode of saving fuel, is to have the tubes or flues pass out of the boiler, *at the lowest part of it*, where the water is coldest, and have the fresh supplies of water pumped in at the same place. The tubes should, therefore, always slope downwards, toward that end of the boiler where they enter the chimney: and it might be well to have that end rather lower than the other. In this way, the heated air may pass off at a temperature, perhaps, of no more than 100°, while the steam, in another part of the boiler, is at a temperature of 300. This method is objected to, because the cooling of the air in the flues will diminish the draught. But where there is an artificial draught, by means of a bellows, the objection will be obviated.

Another method of saving heat, is by condensing the steam that has been used, into the water that is to be used, so as to heat it. This principle is adopted to a certain extent in the Sans Pareil. The plan of the Novelty, of carrying water with the engine, is particularly favourable to its adoption.

The use of small pipes, as in the Rocket, is favourable to the saving of heat; and the smaller they are, the better, so that they can be cleansed in case of stoppage.* The principle on which heat is conveyed from the air in the tubes, to the boiler, is this: the hottest air, being lightest, rises highest, but on touching the surface of the tube, it loses a part of its heat, and, becoming heavier, descends, and other air supplies its place and goes through the same process. From this it is evident that the air in a small tube, will become far more completely cooled in passing the same distance, than in a large tube. The thinness which the small tubes admit, also aids the process. The tubes of the

* The downward direction of the tube, as in the Novelty, will aid greatly in preventing its becoming choked.

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Rocket are very properly made of *copper*, as that metal conducts heat more rapidly than iron.

Such are the methods by which fuel may be economized. This object, however, is of less importance where coal is abundant, than that of obtaining great power in the engine, in proportion to its cost and weight; for fuel is but a small part of the expense of transportation on rail-ways, near coal mines.

The greatest saving of fuel that had been attained in 1825, was the conveyance of 56¼ tons (including engine), 1 mile, with 51,55lbs. coal.—Wood, p. 264.

The Rocket is said to have consumed about half a ton of coal in going 70 miles, with a load of 17 tons, including the engine, which gives about a pound per ton to the mile. But she made many stops, as the route was by going and returning on a plane of 1½ miles long: and she would doubtless have consumed less coal in proportion, when she carried greater loads.

The Sans Pareil consumed more than the Rocket. The owners of the Novelty *professed* to be able to travel with one-third of a pound of coke per mile to each ton of wagons and goods. And they actually succeeded in using no more than nine twenty-fifths of a pound per mile to each ton, while the engine was under way at full speed: the trips being but one and a half miles each. But it is presumable that steam, accumulated at the ends of the trips, was expended during the travelling, so that the real quantity of coal was more than the above.

The steam was up in the experiment for six and a quarter hours, during which time the tons carried were equivalent to 960½, for a distance of one mile, and the coke consumed was 526lbs., besides 52lbs. in getting up the steam. There was doubtless a loss of heat, from stoppages at the ends of the plane: so that we may presume the real expenditure, if the voyage had been directly onward, would have been not more than half a pound per mile to each ton.

Messrs. Braithwaite and Errickssson, after this experiment, proposed to contract with the Directors, to supply engines

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not exceeding 5 tons in weight, that should draw 100 tons gross weight, at 15 miles an hour on perfectly clean and level roads, with a consumption of coke not exceeding one-third of a pound per mile to each ton.

This would be far within the effect of coal as estimated by Mr. Tredgold, applying his estimate to wagons having a friction of one three-hundredth part of their weight.

The following is Mr. Tredgold's Table:

Maximum Power of the Steam of a Cubic Foot of Water, in High Pressure Steam Engines.

Temperature of Steam.	Total force of Steam, in inches of Mercury.	Force of Steam in lbs. per square inch, above the atmosphere.	Maximum Mechanical Power of the Steam of a Cubic foot of Water, in lbs. raised one foot high.		Proportion of the stroke to cut off the Steam to obtain the Maximum by expansion.	lbs. Newcastle coal to convert 1 cubic foot of Water into Steam.
			When working at full pressure.	Acting expansively.		
	inches.	lbs.	lbs.	lbs.		lbs.
220°	35	2.5	negative.	negative.		8.5
234½	45	7.4	287,000			8.67
251	60	14.8	864,000	985,000	3-4	8.87
275	90	29.7	1,495,000	1,927,000	7-12	9.16
292.8	120	44.5	1,830,000	2,540,000	1-2	9.37
307.7	150	59.3	2,054,000	2,988,000	9-20	9.55
320.2	180	74.2	2,202,000	3,326,000	5-12	9.7
343.6	240	104	2,444,000	3,832,000	3-8	9.98

The above estimates give but three-fourths of the effect to 1lb. of coal, which has actually been obtained in *condensing* engines. One of Wolfe's engines at Wheal Abraham mine, raises 44 millions of pounds of water 1 foot high, with a bushel (about 84lbs.) of good Newcastle coal.—*Tredgold*, p. 166.

According to the experiments of Mr. Marcus Bull, 7lbs. of Schuylkill coal are equal to 10lbs. of Newcastle coal. Hazard's *Penn. Register*, vol. 4. p. 100.

It is an inquiry of interest, what is the amount of work which may hereafter probably be done on rail-ways, of the most improved construction, with a certain quantity of coal, and at a certain cost on a level rail-way.

If friction of carriages be reduced to 1lb. in 600, then 1lb. of Schuylkill coal, with steam at 104 lbs. pressure to the inch, should, according to Mr. Tredgold's estimate,

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convey 22 tons (including carriages), 1 mile on a level railway. And 11lbs. coal to each ton of goods, would be sufficient for transportation from the Schuylkill coal mines to Philadelphia, and the return of the empty wagons. Eleven pounds coal will soon be bought at the mines for half a cent (or $1 per ton). Making the cost of coal ½ a cent for conveying 1 ton 100 miles to tide water.

Whether these results will ever be attained, time must determine.

At the rate already attained by the Novelty, with wagons of the old construction, 5 cents worth of coal at the mine, is sufficient for transportation of 1 ton to Philadelphia, and the return of the wagons.

Of Adhesion to the Rails.

The obtaining of the greatest adhesion of the engine wheels to the rails, so as to draw heavy loads up ascents of steepness, is a prime desideratum. We have seen that the adhesion at the maximum short of abrasion, is 1lb. in $2\frac{3}{10}$lbs.:* and the weight necessary to attain this, is 709lbs. on the square inch. This, if upon wheels connected together, like those of the Sans Pareil, and the Killingworth engine, should produce an adhesion of 1233lbs. on 2 inch rails, 1849lbs. on 3 inch rails, and 2466lbs. on 4 inch rails: and the proper weight of engine to attain this adhesion, should be from 1½ to 2 tons, on 2 inch rails, and the others in proportion. Engines of the weight of the Rocket, are therefore sufficient to give the necessary adhesion, on the 4 inch rails.

The loads drawn up ascents of 60 feet to the mile, allowing 1lb. in 300 for friction, would be, including engines and wagons:

With 2	inch rails,	41	tons.
With 3	" do.	60½	tons.
With 4	" do.	82	tons.

* *Ante* p. 27.—Tredgold, by trying an empty carriage, estimated the adhesion at but 1 lb. in 6: but we have seen from Rennie's experiments, that an increase of weight more than doubles the proportionate adhesion.

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With engines like the Rocket and Novelty, having only two of their wheels obliged to move with the engine, the quantity would be one half the above. But their adhesion would be nearly sufficient to draw the above named quantities on a road rising but 27 feet in the mile.

If more adhesion is wanted than the smooth 4 inch rail will afford, the cog wheel and rack rail of Mr. Blenkinsop, already described, may be used, being geared so as to revolve with the other wheels, and the rack rail being laid only where the ascent is great, and only on the ascending track. It has been proposed to place it between the other rails, so that a cog wheel on the middle of one of the axles may run in it.

Perhaps a better plan, would be to have the engine wheels, or the two hinder wheels of the engine, made 4 inches broad, with the outer part of the rim to the width of two inches, *indented* with cogs. The outer part of rails 4 inches wide, might be raised into cogs of the width of 1½ inch, to correspond with cogs on the wheels. This might be done by passing iron plates through rollers properly indented, so that the cogs on the outer part of the rail would be raised above the general surface of the iron, sufficiently to take hold in the indentations upon the engine wheels.

Friction upon, and Injury to the Rails.

The heavy engines on the Stockton and Darlington railway, are said to have their wheels worn into grooves, which injure the rails, and twist them out of place, so that men are kept almost constantly employed to set them right. This inconvenience will probably be avoided by the use of light engines. If we can reduce the weight so that it will not be sufficient to abrade the rails, when the wheels slide over them, the wheels will not wear into grooves for a long time, and the rails will suffer little injury.

There will still, however, with ordinary carriages, be two kinds of friction which it would be well to avoid. One is the rubbing of the flanges against the rails: the other the slipping of the wheels forward or backward in making turns,

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in consequence of the outer wheel having farther to travel than the inner. This can be remedied in the wagons for burthen, by modes already mentioned: but it is more difficult to do it with engines, and not encounter a greater inconvenience.

If the road makes turns equivalent to a complete circuit for every mile, which is far more than is to be expected in any case, the outer engine wheels would have to slip over a distance of 30 feet, if the rails were five feet asunder. Half the weight of the engine would be subjected to this friction. Allowing the friction to be 1lb. in $2\frac{3}{10}$lbs., the total amount would occasion an average resistance on the whole distance travelled, of only one eight-hundred-and-ninth part of the weight of the engine. The sum of disadvantage is, therefore, small.

It is very doubtful whether it can be overcome advantageously. Any variations of machinery, for the purpose, must involve increased expense, and probably increased friction. The difficulty might in some measure be obviated, perhaps, by allowing a space of about half an inch on the engine wheels between the flange and the rail, and having the wheels conical, like those of Mr. Wright, and the rails sloped to conform to them.

William Howard, Esq. of Baltimore, has patented a Locomotive Engine Carriage, having in view the attainment of the two objects of keeping the axles always at right angles with the rails, and allowing the outer wheels, where the road is curved, to move faster than the inner ones.

He proposes to accomplish the first object by having the weight of the boiler rest on the centres of the axles, round which centres the axles are at liberty to play; the axles are connected together by a beam passing from one to the other, which beam is divided in the centre, and provided with a tooth and socket, which permits one end to play in the other. This contrivance obliges the hinder wheels to follow the forward ones.

To allow of the play of the axles without interference

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with the piston rod, the cross-bar at the head of the piston rod is connected by a bolt, so that the bar can revolve; the guides in which the ends of the bar move, are made fast to the ends of the axle, and turn with it. These guides are kept perpendicular by having their upper ends fixed in a frame, in which they are at liberty to slide backwards and forwards, as the axle changes its position. To preserve a uniformity of motion, the heads of the piston rods are connected by a longitudinal balance beam, so that one piston cannot move faster than the other.

The outer wheels on a curved road are allowed to move faster than the inner ones, by being left at liberty to move round the axle so as to revolve faster than the axle; but they are not allowed to move slower, being prevented by a catch and spring, which work on a ratchet wheel, to which the rods upon the cross-bar of the piston rod are attached.

Plate 1, fig. 5, shows a drawing of this carriage; *aa* are the upright supports or guides to the shackle bars. These guides are connected at top by a bolt so they can move horizontally in the frame *bb*; *c* is the joint in the beam which connects the axles; *dd* are the ratchet wheels so connected with the main wheels that the latter can move faster but not slower than the former.

The rest of the drawing will be sufficiently understood.

The objections to this carriage may be: 1. That the two pistons are at their dead points at the same time, so that the motion will be irregular. 2. The resting of the whole weight of the boiler and machinery at single points, on the centres of the axles. 3. The difficulty of keeping the guides of the cross or shackle bars sufficiently steady. These objections do not apply to the ratchet wheel, which is the most valuable part of the plan, as it is of much more importance to allow one wheel to move faster than the opposite, than to have the axles at liberty to assume different angles. The curves are so gradual on rail-roads that the latter object is of little consequence.

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It appears probable, however, that no mode of preventing any considerable slipping of the wheels can be so simple and unincumbered, as the adoption of conical wheels with rails to fit them.

The iron plates for the rails, might be made $\frac{1}{16}$ of an inch thinner at their inner than their outer edges; the rims of the wheels having the same slope. The axles may be fast, but should be placed as near each other as practicable, like those in the Sans Pareil Engine, so that they will have very little tendency to assume different angles.

Safety.

It being impracticable to use condensing engines on railroads, on account of the great weight of the necessary water, it will be important to make high pressure engines of such construction as to avoid the accidents that sometimes occur.

The obvious mode of doing this, is to use boilers of small diameter. This will not only diminish the danger of explosion, but in a still greater degree, the danger of injury in case of rupture of the boiler. By considering the danger from the bursting of a cracker, compared with that of a musket, or that of a musket compared with that of a cannon, we have a comparison of the danger of small boilers compared with large.

Besides the diminished danger of injury from the bursting material, we have in the small boiler little danger of scalding, from the small quantity of water used.

Various modes of using boilers of small tubes, have been tried by Buchanan, Perkins, Babcock, and Wadsworth. Most of these have failed of practical success; from the application of the heat to the outside of the boilers, in such manner, that a great portion was wasted.

But the mode of tubes *within* the boiler used in the engines of the Rocket and Novelty, obviates the difficulty.

I believe there has been no instance of loss of life from a boiler of small diameter.

One half the sum of the pressure of steam, upon as many

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inches as there are in the diameter of the boiler, constitutes the force tending to rupture the boiler.

Take steam at 150lbs. to the inch, the following will be the sum of the pressure at any one place tending to burst the boiler.

Boiler	12 inches	diameter,	900 lbs.
do.	24	do.	1800 "
do.	36	do.	2700 "
do.	48	do.	3600 "

And as the stress is similar to that upon a rod hanging perpendicularly with a weight attached, which will sustain 76,400lbs. to the square inch of iron, the following should be the thickness of the boilers, if we allow eight times the strength equivalent to sustain the pressure.

Diameter of Boiler,	Thickness of Iron.
12 inches.	$\frac{1}{10}$ in. nearly.
24 in.	$\frac{2}{10}$ "
36 in.	$\frac{3}{10}$ "
48 in.	$\frac{4}{10}$ "

The above comes near the thickness generally used for the larger boilers: but many boilers having the outer surface exposed to the heat, are in far more danger of bursting, than those where the heat is enclosed. The kind of iron abovementioned, will therefore be of more than sufficient thickness for boilers, the outside of which are not exposed to the action of the heat.

A supposed danger on rail-roads is, that of the carriages running off the rails. If this be feared, more perfect safety can be obtained by adopting the conical wheels, or by a method already practised, of raising the rail on the outer side of the curve, a little higher than the other, so as to counteract the tendency of the carriages to run off, as well as diminish the friction of the flanges of the wheels against the rails. The practical danger with this safeguard is little or nothing.

Adaptation of Parts of the Engine.

It is important that the cylinders, pistons, boiler, and

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furnace of an engine, be properly proportioned to each other, so that the boiler have the proper extent of surface exposed to heat, to generate steam fast enough for the size of the pistons and the desired speed of the engine, and the furnace be capable of burning coal fast enough to produce the requisite quantity of heat. Any excess in either part, would add unnecessarily to the weight of the engine, while a deficiency would diminish its power.

The proper proportions are yet to be ascertained by experiment: for, as I presume the bellows apparatus will be hereafter used, a much smaller furnace will suffice, than when the atmospheric draught alone is relied on for combustion. And as the boilers having small tubes will probably also be used, we must ascertain how much faster they will conduct heat than the large flues of thick iron.

I presume, if copper tubes of 1 inch in diameter be used, a surface of 36 square inches will be sufficient to boil one gallon of water per hour. For each gallon 1½ to 2lbs. of anthracite coal may be required. And the average effect of each gallon of water converted into steam, will probably be equal to 400,000lbs. raised one foot high.

If then, it be wished to have the engine of sufficient power to move a resistance of half a ton* (on ascents), at the rate of six miles an hour, the surface exposed to heat should be 18 square feet; the quantity of water 72 gallons per hour converted into steam; and the quantity of coal burned from 118 to 144lbs. per hour.

Twelve tubes of 1 inch diameter, and six feet long, would give the 18 feet of surface, which, in addition to the surface exposed around the furnace, would probably be sufficient. Experiment, however, must decide this.

If it be desired that an engine shall be capable of great variety in the velocity of its motion, so that it can ascend hills with a slow motion, and travel on levels with great rapidity: then it will be necessary that the piston stroke be a *long* one, in proportion to the diameter of the wheels, so

* Half a ton raised perpendicularly.

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as to work slowly under a heavy pressure of steam, upon ascents, and rapidly, with lighter steam, on levels. Of course the diameter of cylinders and pistons will be less than if the stroke were short. The Novelty's engine is incapable of ascending hills with a considerable load, because her piston stroke being but 12 inches, the pressure would be so great as to stop the engine. She is calculated only for rapid travelling.

It would probably be best, if uniform velocity could be had, to have the piston move with a very slow motion. But on rail-roads made with economy, there must be great variety of motion, in order to attain the full power of the engine. There will be but little loss of power in great velocity of piston; for the motion of steam is so extremely rapid, that it can follow the piston with nearly its whole force, at a great speed.

Gaseous bodies will rush into a vacuum with the same velocity which a heavy body would acquire in falling through an atmosphere of uniform density, and of sufficient height to produce the degree of pressure to which the gaseous body is exposed.

One hundred cubic inches of steam under a pressure of 15lbs. to the inch, weigh about 19 grains.* Consequently 15lbs. of steam, in a column of 1 inch square, will be 46,141 feet high, if of uniform density. The velocity of a falling body being in proportion to the square root of the distance fallen, allowing a heavy body to fall 16 feet in the first second, and acquire a velocity of 32 feet per second at the end of the first second, then the velocity acquired in falling 46,141 feet, would be 1720 feet per second nearly; which is the velocity with which steam under a pressure of 15lbs. per inch would rush into a vacuum. 1720 feet per second, is 1172 miles per hour,—the velocity with which steam can follow a piston without exerting any force upon it. If the piston moves at 11 miles an hour, the steam will lose but one hundredth part of its force. With 4

* Gay Lussac.

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feet wheels, and the piston having a 24 inch stroke, the carriage would move 3 times as fast as the piston, or 33 miles to 11 of the piston. Therefore, at whatever speed the carriage moves, there can be little loss from velocity of piston, unless it arises from the friction of steam against the sides of the cylinder.

If the piston be small, with a long stroke, less strength and weight will be necessary in the working parts of the engine.

If the piston rod be connected with the spokes of the wheel, half way between the axle and the rim, the strain upon the wheels would be less, and less strength and weight would be required than in the wheels of the Novelty, where the connexion is through the axle.

Of Locomotives for Horse or Ox Power.

At the Liverpool contest, an engine called the *Cycloped*, made by Mr. Brandreth of that place, was exhibited. It consisted of a carriage worked by two horses standing within the wagon and carried along by it.

The wagon was moved by two endless chains, running over the axles, with cross bars attached to the chains, upon which the horses stood, and by stepping gave motion to the cross bars and chains, and thence to the axles and wheels, the horses drawing by a chain attached to the end of the wagon, so that, as they could not leave their places, the platform on which they stood necessarily moved, in the manner of some horse boats on our rivers.

Mr. Winans, also, it is said, has devised a carriage to be moved by horses riding in it.

It is highly probable that this mode of applying power will be found advantageous. Suppose the friction of carriages shall be practically reduced to one 600th part of their weight; the carriages, then, on a road constructed with tolerable economy, would move two-thirds of the distance without any power applied; for the descent of a small hill would give sufficient impetus to the wagons to carry them to the foot of the next hill, so that on an undulating

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road, the only occasion for drawing, would be up hill. The horses standing in the carriage, and their motion being communicated to the main wheels by a ratchet wheel, whenever the carriage would run from its gravity, the horses might stand still, and acquire strength for the next ascent. Every diminution of friction diminishes the advantage of steam power, for the steam engine being expensive, and working but a part of the time, loses its advantages.

But the horse can exert an irregular power with almost as much effect, as if he worked constantly.

The horses in this way, may work in hot weather under a constant shade. They may move but two miles an hour, while the wagons go 10 miles, so that passengers may be carried at the same time that goods are transported. The expense of horse paths will be saved, and the roads kept clear of dust. Cheap rail-roads will then answer for travelling at any speed: for the weight of the horses will not require the substantial construction necessary for steam engines. The rails never being subjected to a weight of more than 2 tons, their supports will be less likely to settle and become uneven. Branch rail-roads of small business, may have their locomotive engines, when those working by steam would be too expensive. The horses of the farmers of a district may be used, when not wanted on the farm, to convey their produce to market on a rail-road, having no towing paths: so that a train of wagons may be kept in each vicinity and used by the farmers in turn.

If friction should be reduced to 1lb. in 600, the effect of a horse would be more than double, in this way, on a cheap rail-road, to what it would be if he walked the whole distance.

It is probable that *ox* power might also be used to advantage, as it is supposed to be much cheaper than that of horses. The reason of its not having been more used, is the impracticability of obtaining speed from oxen. But by means of engines of this kind, while the oxen move at the sluggish pace natural to them, the passengers drawn by them, will move with a velocity extremely unlike the mo-

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tion of Don Quixotte in his supposed enchantment when drawn by oxen.

By regulating the size of the drum or wheels over which the chains move, in proportion to that of the carriage wheels, any desirable degree of speed may be attained.

CHAP. V.

Of Stationary Power.

Where there are unavoidable hills or mountains too steep for locomotive engines to ascend, and tunnels or deep cuts would be too expensive, two kinds of stationary power are used: the one, self-acting planes: the other stationary steam engines.

Self-acting planes are those where the wagons which descend a hill or mountain, by their gravity draw up other ascending wagons. Consequently they are only adapted to places where the greater portion of tonnage passes in the direction of the descent.

As the overcoming of acclivities by steam or horse power is very expensive, the adoption of self-acting planes, where practicable, will generally be found expedient.

The objection made to them is, that they occasion delays and embarrassment, from the necessity that carriages going in both directions, should meet at the self-acting plane at the same time.

I would propose to obviate this difficulty, by having a number of spare wagons loaded with stone, kept constantly on the ground to act as a balancing weight, being sent down the plane when wagons are to be drawn up, and being drawn up when business wagons are passing down. The requisite number only, may be used in each case; and when trains of business wagons meet, none of the spare ones need be used, unless for the purpose of giving the proper proportions to the weight of the respective trains.

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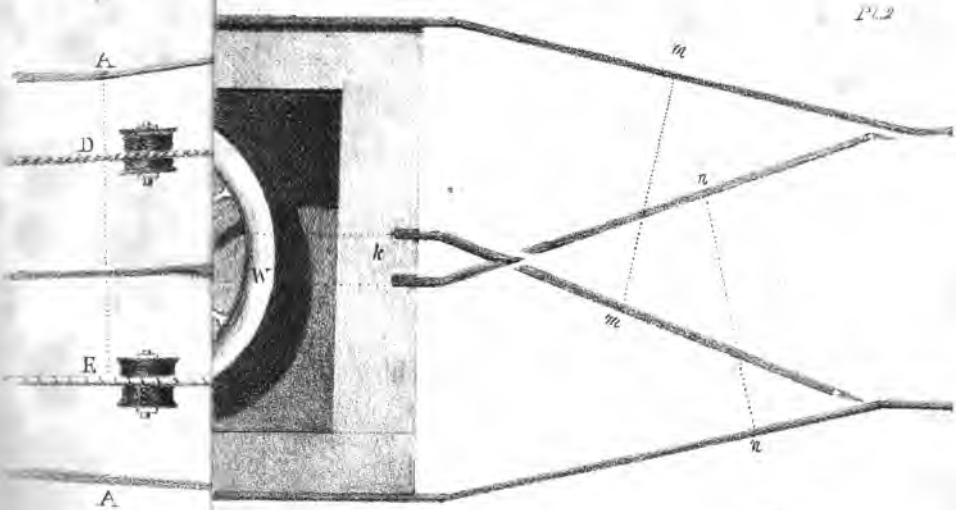

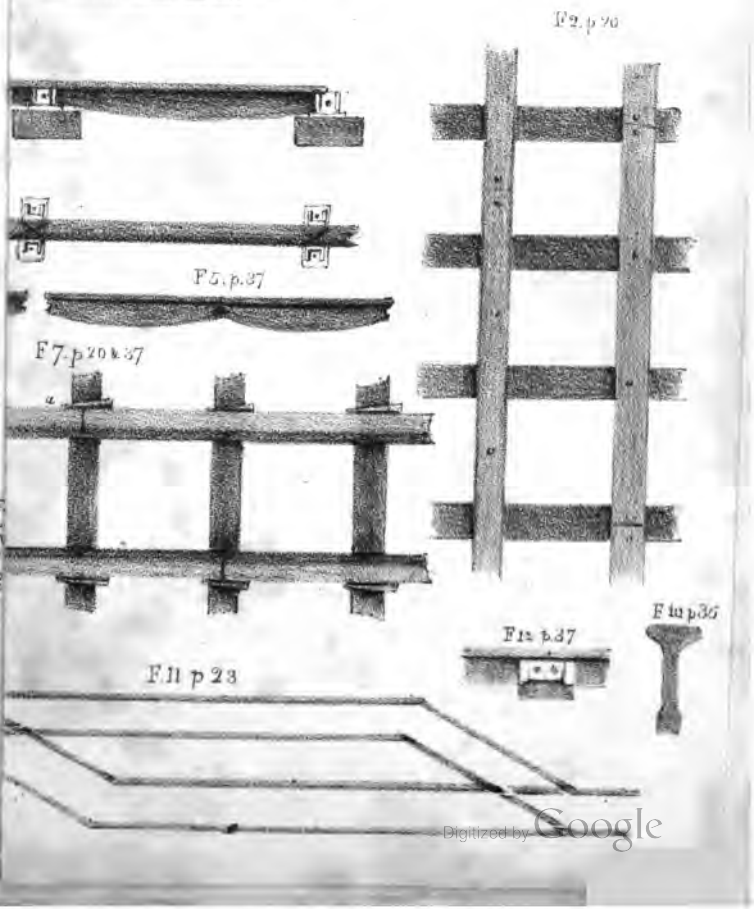

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The only objection to this course, is the increased friction from the ropes running up and down the plane a greater number of times than if none but the business carriages were used: but this objection will be of no moment where the preponderance of goods in one direction is very considerable, so that the descending trains will be more than sufficient to raise the ascending ones.

On the eastern side of the Alleghany mountain, on the Pennsylvania canal route, an ascent of about 1200 feet is proposed to be overcome by inclined planes. In this place, owing to the transmission of agricultural produce from the Ohio, salt from the Kiskiminetas, and bituminous coal and timber from the western side and top of the mountain, it is probable that the descending tonnage will be four times as great as the ascending. Then as descending carriages, on planes properly constructed, will raise about three-fourths of their own weight, there can be no difficulty on the Alleghany, if a proper number of spare wagons are provided to accommodate the trade at all times.

The descent may, also, if necessary, be aided by the use of *water*, as proposed by Moncure Robinson, Esq. a skilful engineer. The plan is to send down carriages loaded with water, and have the water discharged at the bottom of the hill, so that the carriage only must be drawn up. This, of course, is only applicable where water can be had: but a great quantity is not necessary, as we may have its power in a descent of hundreds of feet, instead of the few feet which it falls in its application to mills. A very small stream will produce a great effect, and in most cases will be found sufficient, (if any aid is needed,) in the direction of greatest transportation. A range of mountains like the Alleghany, can generally be crossed at points low enough to afford the use of considerable streams, which rise on higher parts of the ridge.

The use of loaded wagons on the Alleghany mountain, in the manner above mentioned, would probably save $15,000 per annum, by avoiding the use of four or six stationary

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steam engines;* and there would be less danger of obstruction to the trade from disorder in the machinery.

We now proceed to describe the mode of operation on self-acting planes.

A pit is dug at the summit of the hill, immediately under the place where the rails are to be laid. This pit is walled with stone work similar to the walling of a cellar. Within this wall a wooden frame is placed, provided with a wheel, inclined a little from the horizontal position, which may be of cast iron. Around this wheel a rope runs, to one end of which the ascending and to the other the descending carriages are attached.

Plate 2, fig. 1, exhibits a top view of this machinery, uncovered; it being understood, that in practice the wheel is covered over with boards, on the top of which the rails are laid, so that the wagons, when at the summit, pass immediately over the wheel.

WW is the wheel; DE the rope; *ssss* are rollers or sheeves, made hollow, of cast iron, over which the rope runs to prevent the wearing and friction, which would occur if it ran on the ground. As the carriages will always pass each other at the same place, about half way down the plane, the railway need not be double all the distance. There are usually three rails near the top of the plane as shown in the plate, which diverge into four at the middle, and converge into two from thence to the bottom.

A plane 3906 feet long and 130 feet 4 inches high, on the Killingworth Rail-Road, has a wheel weighing 454 lbs.; its diameter is 6 feet. The circumference of the rope is 5 inches, and its weight 4807 lbs. The sheeves or rollers on which the rope rests, are 288 in number, and their weight 8896 lbs.

The above named rope is of sufficient strength to be used with carriages weighing with their loads 11 or 12 tons, attached to one end of the rope, and a proportionate load to the other.

The friction of the ropes has been ascertained by numer-

* Mr. Robinson, the Engineer employed on the route, has proposed the use of self-acting planes.

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ous experiments of Mr. Wood, to amount to nearly one-third of the weight of the whole carriages and apparatus moved. This is when there are no sheeves or rollers to support the rope. But by the use of the sheeves the friction may be reduced in the proportion of the diameter of the sheeves to that of their axles. In this way the actual friction may be reduced, if necessary, as low as $\frac{1}{100}$ of the whole weight.

In this case, on a plane descending 1 foot in 25, or 211$\frac{1}{3}$ feet to the mile, the descending tonnage would draw more than two-thirds its weight up the plane, after allowance for friction.

Consequently, in many instances, where the descent is in the direction of greatest transportation, the use of self-acting planes will answer every purpose; for if the proportion of ascending tonnage should at any time be too large, horse power might be used in aid of gravity, or steam power if the transportation be by locomotive engines; and the travelling horses or engines would furnish this power.

The average cost of the machinery for self-acting planes of about 200 feet lift, is estimated at from 3000 to 4000 dollars per mile; and the average expense of attendance, at $1000 per year, by Moncure Robinson, Esq.

Of Stationary Steam Engines.

The use of Stationary Engines on inclined planes will be readily understood. There are various modes of organizing the machinery. The most simple and advantageous is that proposed by Mr. Tredgold.

The stationary engine may be fixed at the top of the plane, and geared to an inclined wheel, like that of the self-acting plane—Plate 2, fig. 1. A similar wheel being placed at the foot of the plane, an endless chain should pass from the top to the bottom, and around both of the wheels, suitable projections being made upon the wheels for the chain to run upon, as well as sheeves along the plane to support the chain and diminish friction.*

* The usual method is by ropes winding up on a drum attached to the engine.

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The plane being so organised, a train of carriages may pass down one side, while another passes upward, and the gravity of the former will aid the power of the engine, and accelerate the motion of the latter.

In many places the descending tonnage will be almost sufficient to raise the ascending, so that an engine of moderate capacity will be sufficient for the purpose, especially as the horses or locomotive engines, which draw the wagons, may assist with their power. A slight deduction from the toll may be made upon descending trains, in case they will wait for an ascending train, or a number of spare wagons loaded with stone may be used to be drawn up when a train is descending, and to descend, and aid the power applied, when a train of carriages is ascending.

As the business for a stationary engine is necessarily irregular, it will be important so to organise the machine, that steam and fuel will not be wasted when there are no carriages passing, and so that the steam can be quickly got up when carriages arrive. This may be easily done by the use of an artificial blast for the engine. The water can be heated in the morning to the boiling point, and kept so through the day, the bellows being blown only when steam is wanted. When they are not blown the fire will be only sufficient to keep the permanent heat, and a small supply of steam in the chamber.

The expense of stationary engines and apparatus, on the west side of the Alleghany, are estimated by Mr. Moncure Robinson, as follows :—

Engine, (of 70 horse power),	$7,500 00
Drum, Brake, and Gearing,	950 00
1830 feet 3 inch hempen cable, weight 5856 lbs. at 14 cents per lb.,	819 84
80 friction rollers, weight 30 lbs. each, delivered and placed at $1,35,	108 00
160 wooden bents for supports, at 25 cents,	40 00
Total,	$9,417 84

The length of cable and number of rollers will vary with the length of the plane.

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The annual expense of such an engine is estimated at 2200 dollars, one half being for attendance, and the other half for fuel.

Comparative Advantages of Locomotive and Stationary Engines.

Some have proposed to adopt stationary engines on the whole route of a railway, to move the carriages by a series of endless chains, working round two wheels at the distance of half a mile or a mile asunder.*

The objections to this plan are various. In the first place, it would be inconvenient to arrange the crossings of other roads, as the endless chains would stop up the crossing road. It would be difficult to loosen, and again make fast the carriages at every new engine and chain, keeping up at the same time a velocity equal to that generally desirable for travellers. The stationary engines, including the fixtures and buildings, would be as expensive in proportion to their power as the locomotives; and the heavy expense of the chains, and rollers or sheeves to support them, in the former case, would be so much extra cost.

There are very few routes where the business would be sufficient to keep the requisite number of stationary engines employed. And if it were sufficient, still the business being irregular, they would have too much work at one time, and not enough at another. If a single engine should be out of order, it would interrupt the business of the whole line; or if, to avoid this, there were two engines at every station, an immense expense would be thus incurred. And the liability of interruption from the breaking of a chain would still remain.

Such plans, therefore, will not, in all probability, be adopted.

Stationary engines for the whole line being rejected, it will still be a question how far they should be adopted on parts of the line.

Suppose the inclination of the road generally not to ex-

* Tredgold, p. 89.

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ceed 30 feet to the mile, but at one place it is necessary to have an ascent for 1½ miles at the rate of 60 or 70 feet to the mile, which the locomotive engines cannot overcome with the loads it is intended they shall carry. In such case stationary engines may be used, or a spare locomotive engine may be kept constantly on the ground to ply up and down the plane, and assist the other engines in raising their loads. The latter course, I think, would be preferable, where the plane was long and the declivity not very great.

If the locomotive engine used in such case, should be out of order, the engines drawing trains of wagons might ascend the hill with half their train and return for the other half.

A Plan

*For reducing a Hilly Road to nearly the same advantages as a Level one, without the use of Stationary Engines.**

Wherever the acclivity of the road is too great for the locomotive engines or horses to overcome, with the loads which it is intended they should carry, let the inclined plane be provided with horizontal wheels and an endless chain resting upon rollers in the manner already mentioned. Have a sufficient number of spare wagons, (which may be made at $60 each) to be kept constantly loaded with stone. To render the friction of these wagons as small as practicable, let the wheels be 5 or 6 feet in diameter—the height of the axle constituting no objection, where the carriages are never to be unloaded.

The engines or horses descending with trains of wagons, are to draw up, by the endless chain, as many spare wagons as equal the weight of the descending train; and the ascending trains are to have the aid of the gravity of as many spare wagons coming down the plane as equal their own weight. If, however, an ascending and descending train meet at the same time, none of the spare wagons need be used, unless it be to equalize the weights.

If, then, the ascending and descending tonnage be equal,

* The author suggested this plan to his friends several months ago. Since that time, a number of the London Mechanic's Magazine, containing a similar plan, has been received.

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all the labour for the horses or locomotive engines to perform will be that of overcoming the friction of the carriages and chain. When two trains going in opposite directions meet at the inclined plane, all the power the locomotive engines must exert over that upon a level, will be to overcome the friction of the chain alone. This, with proper rollers, is estimated by Tredgold at $\frac{1}{100}$th part the power of the proper sized engines on a plane of half a mile in length, or $\frac{1}{50}$th part on a plane of a mile in length. But the chain will be heavier on an ascent than on a level. Suppose its friction to be $\frac{1}{30}$th part of the power of the locomotive engine. Then when one engine is ascending and another descending, each will have to exert $\frac{1}{72}$ part of its power on the chain. This is equal to an ascent of $\frac{1}{4}$ of a foot to the mile. The engines would therefore travel with the same speed as up an ascent of $\frac{1}{4}$ of a foot to the mile; and this speed would be only $\frac{1}{72}$d part less than on a level.

But if ascending and descending trains did not meet at the plane, then the spare wagons must be used, the friction of which, added to that of the chain, would be about equal to that of the carriages attached to the engine: the engine would therefore have to expend half its power on the chain and spare carriages, and its speed would be the same as up an ascent of 18 feet to the mile. To avoid this inconvenience, the proprietors of locomotive engines would arrange their business as far as conveniently practicable so as to meet at the inclined planes.

The above observations suppose an equality of transportation in both directions. When the amount is unequal, it will generally favour the facility of operations, because the greatest descent is towards the sea, and the greatest amount of tonnage is usually in the same direction.

But take the case of a hill *to be passed over* with a steep descent on both sides. The operation can easily be conducted in this case, by having the endless chains on each side of the hill connected by gearing at the top, (capable of being thrown out of gear when necessary) so that the wagons descending in the direction of greatest transportation, may

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be made to draw, or assist in drawing wagons up the other side of the hill. In this way, every train may have a load to balance it, and the only power the engine will exert will be to overcome the friction of the chains and carriages. If the declivity be the greatest on that side of the hill on which the most goods descend, the engines will receive actual aid in overcoming friction from the gravity of the wagons. The average power exerted by the locomotive engines on such planes, would probably not exceed that ordinarily necessary to ascend at the rate of 10 or 15 feet to the mile. The planes may be a mile long on each side of the hill, and the ascent and descent each 200 or 300 feet, if the hill be sufficiently steep to admit it. The loaded wagons to balance the travelling trains, might be kept almost constantly hitched to the chain, and resting at the top of the hill. Each engine in ascending the hill would lower these wagons, and in descending the other side would raise them up, and leave them ready to assist the next engine. A considerable variation between the weight of the passing train and that of the spare wagons might occur without a necessity of altering the latter, for the power of the locomotive engine would overcome the inequality.

There is yet another case which will sometimes, though rarely, occur. It is that of an ascent in the direction of most transportation, too steep to be overcome by the simple locomotive engine with its proper load, and unaccompanied by a descent in the other direction: in other words, a hill with a level plane at its summit.

Even in this case, if the ascents be not very steep, there will be no necessity for stationary power. If the carriages weigh one-third as much as the loads, and there be three times as much tonnage in one direction as the other, then engines which can draw their loads up an ascent of 36 feet to the mile, can overcome one of 72 feet per mile, by the aid of the endless chain and the loads which the descending engines can raise upon the plane. In this calculation, the friction is estimated 1 in 300, and the descending engines

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are supposed to exert their full power on spare wagons which ascend at the same time that the engines descend.

If the plane be steeper than above mentioned, a horse may be used in aid of the other power, and the necessity of a stationary engine avoided, if the business of the road be not extensive enough to afford one.

The adoption of the above plan, would, in many cases, avoid expensive deep cuttings, or the making of the road circuitous. It is the least expensive mode that can be devised to cross a hill which cannot be gone round without inconvenience and cost.

Plate 2, fig. 13, represents the manner in which an endless chain or rope might be placed to assist locomotive engines in going over a hill; *aa* are the wheels at the top of the hill, and *bb* the wheels round which the rope or chain winds at the foot on each side.

A train of loaded wagons might be attached, so that as each engine went up the hill, the train would descend; and as the engine descended, the train would ascend, and be left at the summit. The wagons attached to the chain having a medium weight, between that of loaded engines, and that of those with empty wagons, the assistance would be sufficient for the former, and the resistance not too great for the latter. Thus no attendant would be required, and the greatest possible economy would be attained.

The cost of such self-acting planes would be proportioned to their length. The following estimate is for one half a mile long:—

5280 feet of $\frac{3}{4}$ inch chain cable, weight 5 lb. per foot, at 13 cents,	$3,437 20
250 friction rollers, at 1,35,	337 50
500 bents to support rollers, at 25 cents,	125 00
Two* horizontal wheels, appendages and brake,	850 00
Total,	$4,749 70

* Four wheels will be required if the machinery extends *over* a hill.

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CHAP. VI.

Of Tunnels.

Instances will probably occur in which tunnels will be advantageous on rail-roads as well as on canals. Two tunnels are made on the Liverpool and Manchester Railway; and one is proposed by Mr. Robinson, on the Allegheny portage, in Pennsylvania.

Tunnels for railways may be made at far less expense than those for canals. The latter must be level, and it is consequently inconvenient to remove the earth, and very expensive to keep them clear of water while the work is going on. But a railway tunnel may have a gradual ascent from both extremities to the middle, so that the water will run out, and the earth may be cheaply drawn out on rails temporarily laid.

A tunnel for a single track will be sufficient, provided there be bells or lights to communicate information when a train of carriages is passing through it. Nine feet in width and nine in height, will therefore afford sufficient dimensions.* This will give 9 cubic yards of excavation for every yard in length. Solid rock may be excavated and removed a short distance, at $2 per cubic yard.† We will, however, put it at $2,50. In no case can a rail-road tunnel, if properly made, be more expensive than through solid rock. The expense, therefore, for a mile, or 1760 yards in length, would be $39,600.

Wherever a tunnel of half a mile, costing $19,800, will avoid a stationary engine, or will shorten the road 1½ mile, it may be expedient to prefer the tunnel.

I am, however, disposed to believe, that the use of planes, on the principle mentioned under the last head, will obviate in many places, the inducements to tunnelling.

There is one advantage of tunnels that requires mention-

* At East Kenton Colliery, near Newcastle, Eng., there is a tunnel 6 feet wide, 6 feet high, and 3 miles long, with a railway through it.

† Maj. D. B. Douglass.—Contracts for small tunnels near Pottsville have been made at a lower rate than $2 per cubic yard.

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ing. They frequently strike veins of coal, iron, or other valuable minerals, which pay for their making and increase the business of the road. Where a mountain abounding in veins of coal can be tunnelled and accommodate the road, it will generally be advisable to do it. It is not improbable that it will be found expedient to tunnel a narrow place in the Broad mountain in Schuylkill County, Pennsylvania, to open veins of coal, and afford a passage for a railway from the Schuylkill to the Susquehanna.

A tunnel of small dimensions can be made much cheaper in proportion, than a larger one, as the large one must have a proportionately higher arch, and will be more difficult to preserve from falling in. It would therefore be very inexpedient, in most cases, to make a tunnel sufficiently broad for a double road.

CHAP. VII.

Comparative Advantages of Canals and Rail-Roads.

Most canals have been made of indiscreet proportions in width, depth, and lockage. A long narrow deeply-laden boat requires much less water and time to pass it through locks, in proportion to its burthen, than a shallow and broad one, the locks being in each case proportioned to the boat.

The narrow boat will be drawn with much greater ease, and will admit of more rapid motion. To test its advantages, I tried an experiment which any one can easily repeat. I made two small model boats of solid wood, both being taken from the same piece. One boat was short and broad: the other was of double the length, but narrow and deep. These boats were attached to the ends of a line, which was doubled over a pulley, and the boats placed in a pool of water, so that when the pulley was moved along by its axis, the boats would follow it, but that which passed with greatest ease through the water would travel the fastest. The invariable result was, that the long and nar-

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row boat, which was the largest and heaviest of the two, gained rapidly of the other.

The proper construction of canals where the amount of transportation is large, is this: width 40 feet: depth of water 5 feet: locks 100 feet long by 11 feet wide: boats to carry 70 tons, with two horses. Where the business is small: width 28 or 30 feet: depth 4 or 4¼ feet: locks 80 feet long by 8 feet wide: boats to carry 30 tons, with 1 horse.

In this chapter I will suppose canals to be of the best construction.

In estimating the comparative advantages of rail-roads and canals of various kinds, we can only arrive at a general approximation to correctness, as peculiar circumstances will vary the results in each case.

The passengers on a rail-road, at a toll of 1 cent each per mile, will generally more than pay the repairs, while on canals they would probably fall short of paying. We will, however, suppose them to pay in both cases.

The expense of attendance on canals, will exceed that on rail-ways, unless there be stationary engines on the latter. We will, however, suppose them equal.

And as in most cases of large business, the transportation is chiefly in one direction, we will base our calculations upon the supposition of its being all in one direction, the carriages or boats returning empty.

Expense of Transportation and Tolls.

1. Canal 40 *Feet Wide:* 5 *Feet Deep:* *Boats* 70 *Tons.*

Transportation.

Boat $500.—Interest and repairs per day,	$0 75
2 horses per day, 50 cents each,	1 00
2 men at $1, and 1 boy at 50 cents,	2 50
	$4 25

70 tons carried 11 miles and boat returned empty in one day, is 1 ton 770 miles for $4 25 cents, or 55-100 of a cent per mile for one ton.

Tolls.

Cost $18,000 per mile, on which 9 per cent. for interest, attendance, and profit, is $1520 per annum on each mile.

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2. Canal 28 *Feet Wide:* 4¼ *Deep:* *Boats* 30 *tons.*

Transportation.

Boat $300.—Interest and repairs per day,	$0 40
2 men at $1: 1 horse at 50 cents: 1 boy at 50 cents,	3 00
	$3 40

30 tons carried 12 miles, and boat returned empty in 1 day, equal to one ton 360 miles for $3 40 cents, is per mile 94-100 of a cent nearly.

Toll.

Cost of canal per mile $12,000—on which 9 per cent. is $1080 per year.

3. Rail-road: Iron and Stone: *grade 27 feet per mile: friction* 1*lb. in* 300.

Transportation.

Engine wt. 4 tons. Cost $3600.—Interest and repairs 20 per cent. per annum, is per day for 300 days,	$2 40
Wagons for 50 tons, cost $2500.—Interest and renewals 20 per cent. is per day,	1 66
Engineer, assistant, and boy per day,	3 50
2500lbs. coal at $3 per ton,	3 35
Oil and tallow per day,	0 74
	$11 65

50 tons carried 50 miles, and wagons returned empty in one day: equal to 2500 tons 1 mile for $11 65: say 47-100 cents per ton 1 mile.

Toll.

Cost of rail-road $15,000 per mile, on which interest and attendance at 9 per cent. is $1350 per annum.

4. Rail-road of Wood and Iron: *greatest graduation* 60 *feet to a mile one way, and* 80 *the other: friction* 1*lb. in* 300.

Transportation.

Engine wt. 3 tons: cost $2800.—Interest and repairs 20 per cent. is per day, for 300 days,	$2 00
Wagons for 30 tons cost $1500.—Interest and repairs at 20 per cent. is per day,	1 00
Engineer, assistant, and boy per day,	3 50
1875lbs. coal at $3 per ton,	2 51
Oil and tallow per day,	0 50
	$9 51

30 tons carried 50 miles in 1 day, and wagons returned empty: equal to 1500 tons, 1 mile for $9 51, or 64-100 of a cent for 1 ton 1 mile.

Toll.

Cost of rail-road, say $7000 per mile, for double tracks, on which interest and attendance at 9 per cent. per annum, is $630.

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5. Rail-road for Horses. *Iron and Wood.* Graduation from 0 to 54 feet per mile: average 18 feet: friction 1lb. in 300. Horses power 200lbs. for 16 miles in a day.

*Transportation.**

4 horses at 45 cents per day,	$1 80
1 man 90, and 1 boy 45,	1 35
Wagons for 36 tons. Cost $1800: interest and repairs at 15 per cent. for 300 days, is per day,	0 99
Tallow for wagons per day,	0 30
Use of extra wagons for horses to ride,	0 10
	$4 44

36 tons carried 15 miles and the wagons returned, the horses travelling 16 and riding 14 miles: equal to 540 tons, 1 mile for $4 44 cents, or 83-100 of a cent for 1 ton 1 mile.

Toll.

Double rail-road. Cost per mile $4000.—Interest, attendance, and profit, 9 per cent. is $360 per year.

TABLE,

Shewing the amount of Tolls per ton, necessary to pay a profit, on Canals and Rail-Roads of various kinds.

Tons per year.	Broad Canal. ts fr.	Narrow Canal. cts. fr.	Rail-road at $60,000 per mile.† cts. fr.	Rail-road at $15,000. cts. fr.	Rail-road at $7,000. cts. fr.	Single road for Steam Engines. cts. fr.	Double road for Horses. cts. fr.	Single road for Horses. cts. fr.
At 600,000 tons	0.25	0.18	0.70	0.23	0.11	0.06	0.06	0.03
At 300,000 tons	0.50	0.36	1.40	0.46	0.22	0.11	0.12	0.06
At 150,000 tons	1.00	0.72	2.80	0.92	0.44	0.22	0.24	0.12
At 50,000 tons	3.00	2.16	8.40	2.76	1.32	0.66	0.72	0.36
At 10,000 tons	1 0	10.80	42.00	13.80	6.60	3.30	3.60	1.80
At 1,000 tons	150.00	108.00	420.00	138.00	66.00	33.00	36.00	‡9.00

The calculations of expense of transportation, page 99, are based on a price of $3 per ton for coal, and on the

* I have estimated the price of men's and horses' labour one-tenth lower per day than on a canal, because they can work the whole year on a rail-road, while on a canal they work only that portion when labour is most wanted for other purposes. The wear of wagons is estimated less than when used with steam engines, because the motion is less rapid.

† Seven per cent. only is allowed on this rail-way for interest and attendance, the passengers being supposed to pay repairs and profits. This is less expensive than the Liverpool and Manchester rail-way.

‡ In this case, the rail-way is supposed to be entirely of wood, at 1000 dollars per mile.

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supposition that the engines will travel 50 miles, with the loads there given, and return without loads, in one day: lest we should be supposed to have made the reckoning too favourable, we will subjoin a table based on a price of $4 per ton for coal; and on the supposition that the engines will travel but 40 miles and return in one day, with the given loads, or travel a proportionably greater distance with a less load.

An addition will be made for windings of the routes, so as to reduce the distance to a right line. The addition is 30 per cent on canals: 12 on rail-roads for engines: and 20 on rail-roads for horses.

TABLE,

Shewing Total Cost of Transportation and Toll per mile in a right line, exclusive of Loading, Unloading, and Profit: The most advantageous Canals and Rail-roads being taken in each case. Steam Engines travelling 80 *miles per day,* 40 *with loads and* 40 *without, with coal at* $4 *per ton: Horses drawing* 16 *miles per day, exerting a power of* 200*lbs.: Friction* 1*lb. in* 300.

Tons per year.	On Canal. cts. & fr.	On Rail-roads. cts. fr.	On Turnpikes. cts. fr.
At 600,000 tons.	1.04	0.98	
At 300,000 tons.	1.37	1.20	
At 100,000 tons.	2.01	1.29	
At 50,000 tons.	3.09	1.67	18.
At 10,000 tons.	10.58	2.44	20.
At 5,000 tons.	19.94	3.88	22.
At 1,000 tons.	94.52	11.00	85.

I have endeavoured to make the calculations as favourable as possible for canals. I have estimated the expense of broad canals 5 feet deep, at an average of 18,000 dollars per mile. But the New York canals, only 4 feet deep, cost upwards of 20,000 dollars; and the Pennsylvania canals of 428 miles, of which but 60 miles are 5 feet deep, cost, on the average, 23,030 dollars per mile. (Canal Commissioners' Report for December 1829.)

I have estimated narrow canals at $12,000, which is below their usual cost.

I have allowed 70 tons to a two horse boat, on a canal, and 2 men and a boy to be sufficient to navigate. The load

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is larger, and the hands fewer, than is usual in practice.

I have supposed the toll on passengers to pay the repairs of both rail-roads and canals; but canals can hardly have passengers after the introduction of rail-roads, while most rail-roads will have more than enough to pay their repairs.

The repairs on a rail-road of iron and stone costing $15,000 per mile, will probably be less than on a canal, as the iron is found not to oxidize when in use. The iron will last more than 30 years, and may then be renewed for 9000 dollars,* 3000 of which will be paid by the sale of the old iron. This will leave $200 a year for renewals, to which we may add $100 for other repairs—making $300 per mile each year. 100 passengers per day for 300 days, at 1 cent toll per mile, would pay this. But a route calling for a rail-road of this kind will have, when travelling is reduced to 1½ cent per mile, more than two hundred passengers per day.†

On a double rail-road of wood and iron for steam engines, the iron costing about 2200 dollars per mile, 60 dollars per year will be sufficient for renewals: and the wood costing about 800 dollars per mile, 100 dollars per year will be sufficient: total 160 dollars yearly per mile, which would be paid by 54 passengers per day at 1 cent per mile.

On a double rail-way for horses, the iron costing less than 1000 dollars per mile,—35 dollars per year will be sufficient for renewals: and the wood costing under 600 dollars per mile, 75 dollars per year will be enough: total 110 dollars, which would be paid by 37 passengers per day: or 19 passengers per day if it be a single rail-way. Thus we see the calculation that passengers will pay repairs, is moderate.

I have estimated canals to average 30 per cent. longer

* Iron strong enough for engines of 4 tons may be bought for $7000 per mile. It will probably last 50 years on the average.

† The number of passengers that arrived at Louisville, Ky. in one week this year, was 1780.

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than a direct route: but the canal route by which the Lehigh coal comes to Philadelphia, is 133 miles from the mine, while the direct distance is but 74 miles, making a difference of 80 per cent. The route from Philadelphia to Pittsburg is, by canal, 440 miles, while on a straight road it would be but 300: making a difference of 46 per cent. On rail-roads for steam engines, 12 per cent is allowed for windings: but those on the Columbia and Philadelphia rail-road, amount to but 10 per cent. On rail-roads for horses 20 per cent is allowed for windings, which is probably far too much.

The interest, repairs, and renewals of steam engines, are estimated at 20 per cent. per annum. But a high pressure engine at the United States' Mint at Philadelphia, has been in constant operation for 16 years, and is now apparently as good as at first. The repairs have not cost more than 1 or 1½ per cent. on its value. The interest, repairs, and renewals of wagons are put at 20 per cent. per annum: but Mr. Wood (Wood on Rail-roads, p. 82), mentions wagon wheels which had been in use for 8 years, and were still in good order, and likely for some time to remain so.

The engines are supposed to travel but 80 miles a day, one half the distance without loads. From the experience of the English, there is reason to believe this is 20 per cent. too unfavourable an estimate. The prices of locomotive engines are probably put too high. They were sold in England five years since, at £600 for an engine weighing 6½ tons, since which the price is reduced.

Coal is put at $4 per ton: but the average price for the supply of engines in Pennsylvania, will not exceed $2, when communications are perfected: and for the greater portion of transportation, the engines will be supplied at the mines at about $1 per ton. The coal allowed in the estimate is 1 lb. per ton a mile on a rail-way graduated at 27 feet: and 1¼ lbs. on one graduated at 60 feet. This considerably exceeds the rate already effected by Braithwaite and Errickssson, with wagons not of the best construction.

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The friction of wagons is put at 1 lb. in 300, which is probably at least double what will be practically attained.

The horses are supposed to ride 14 miles to travelling 16 miles: but they can do more, as when wagons are improved, the descent of each acclivity will carry them over the succeeding level.

As these estimates are apparently so moderate, it may be asked, why does transportation at Mauch Chunk cost 3 or 4 cents per mile, as stated in some publications. The answer is plain. The rail-way is unfavourable, from the descent being near 100 feet to the mile, and continued for more than 8 miles: making the hauling of empty wagons more expensive than that of loaded ones on other roads. The wagons are too heavy, weighing 1600 lbs., to carry loads of 1½ tons. The wheels are too low, being little over two feet, which occasions violent shocks, as well as great heat, friction, and wear on the axles. The waste of oil ($2000 worth to convey 87,000 tons), is enormous: if the wheels were of proper diameter, and tallow, or tallow and black lead were used, the expense would be reduced probably nine-tenths.

We have heretofore spoken merely of expense: but there are various other considerations connected with the subject. Rail-roads may be used at least 11 months in the year: canals in a northern climate, not more than 8 months. The hands are employed on canals when their services are wanted elsewhere, and they are unemployed when there is no other work to be had. The business of canals must be limited, from the inconvenience of conveying goods to the canal and unloading and reloading to be carried a few miles upon it. But as branch rail-roads can be constructed at any price down to 600 dollars per mile, branches will be run to every village contiguous to the line, and goods will come in on those lines and proceed without obstruction on the main line, increasing the convenience and profit of the improvement.

Carriages for burthen may travel on rail-roads fast enough

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for the conveyance of passengers also, and the receipts for passages will enable a reduction of the charges for freight: but on canals separate boats must be employed for passengers, and the speed still slow, while the power exerted by the horses will much exceed that on a rail-road, owing to the great increase of resistance from the water whenever speed is accelerated. For this reason, passengers can be carried on a rail-road cheaper than in steam-boats.

The celerity of transportation is a great object in many cases. This can be effected on rail-roads, but not on canals. Certainty is another important object. Canals are very liable to interruption from breaches in the banks, or giving way in aqueducts, &c. News was received in one day this season, of the stoppage of three lines in Pennsylvania, viz. the Schuylkill, the Susquehanna, and the Alleghany. But rail-ways will rarely be interrupted, as in case of any accident to one track, the carriages can turn on to the other track and pass the imperfect place.

A further advantage of rail-roads is in the accommodation they will afford to farmers for the transportation of lime, plaster of paris, or other manure for fertilizing their land. These articles by branch roads can be advantageously conveyed to every neighbourhood.

They will accommodate large cities and the surrounding country, by conveying fresh milk, butter, vegetables and fruits, from a great distance in a few hours.

They will accommodate towns and villages on the sites generally chosen, namely, those which are high and healthy, and will furnish inducements to establish towns in such places in preference to those which are low and unwholesome.

It requires a number of years to complete a canal and get it in order, the owners losing the interest of their capital during the time: but a rail-way of considerable length may be completed in a single year.

From all these considerations, there can be little doubt, that although canals may be found preferable in some cases, yet in four out of five a rail-way will be preferred.

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The experiment of rail-ways has been pretty fairly tested by several years experience on the Stockton and Darlington rail-way, in England. The stock has greatly risen. The passengers and the trade on the line have increased four-fold: and the impression made on the public mind is such, that while no one thinks of making canals, rail-ways would be made in many sections of the country where they must encounter the competition of canals already established, were it not that the government will not grant charters.

We will here offer a few observations on the kind of rail-roads which will probably be found ultimately preferable. The expense of transportation will be diminished by improvements in wagons. Every diminution diminishes the inducements to expensive roads, because the tolls on these become more costly than the whole expenses on cheaper works.

If the powers of horses or oxen can be advantageously applied to a carriage, *in which they ride,* it will probably supersede the use of steam, because the former can be applied profitably on roads requiring, by reason of their undulation, no power exerted for the greater portion of the distance. The loads may be light, and consequently the rails and their foundation cheap,* while the tendency of the heavy weight of the steam engine requires expensive rails and expensive foundations.

If this mode of applying animal power shall not succeed, then light steam engines, probably of a weight not exceeding two tons, will be used. The average velocity in either case will probably exceed ten miles an hour, so that trains for burthen will also carry passengers. If the wheels are of 5 feet diameter, and the axles not exceeding $1\frac{1}{2}$ or two

* A kind of sleepers well calculated to prevent the *settling* of the ends of the rails may here be mentioned. Split the trunks of trees in halves, and lay the flat sides down, cutting the grooves for the rails in the round side. The flat side, having great breadth, will give a large bearing surface on the earth, so that the liability to settle under the weight of carriages will be diminished.

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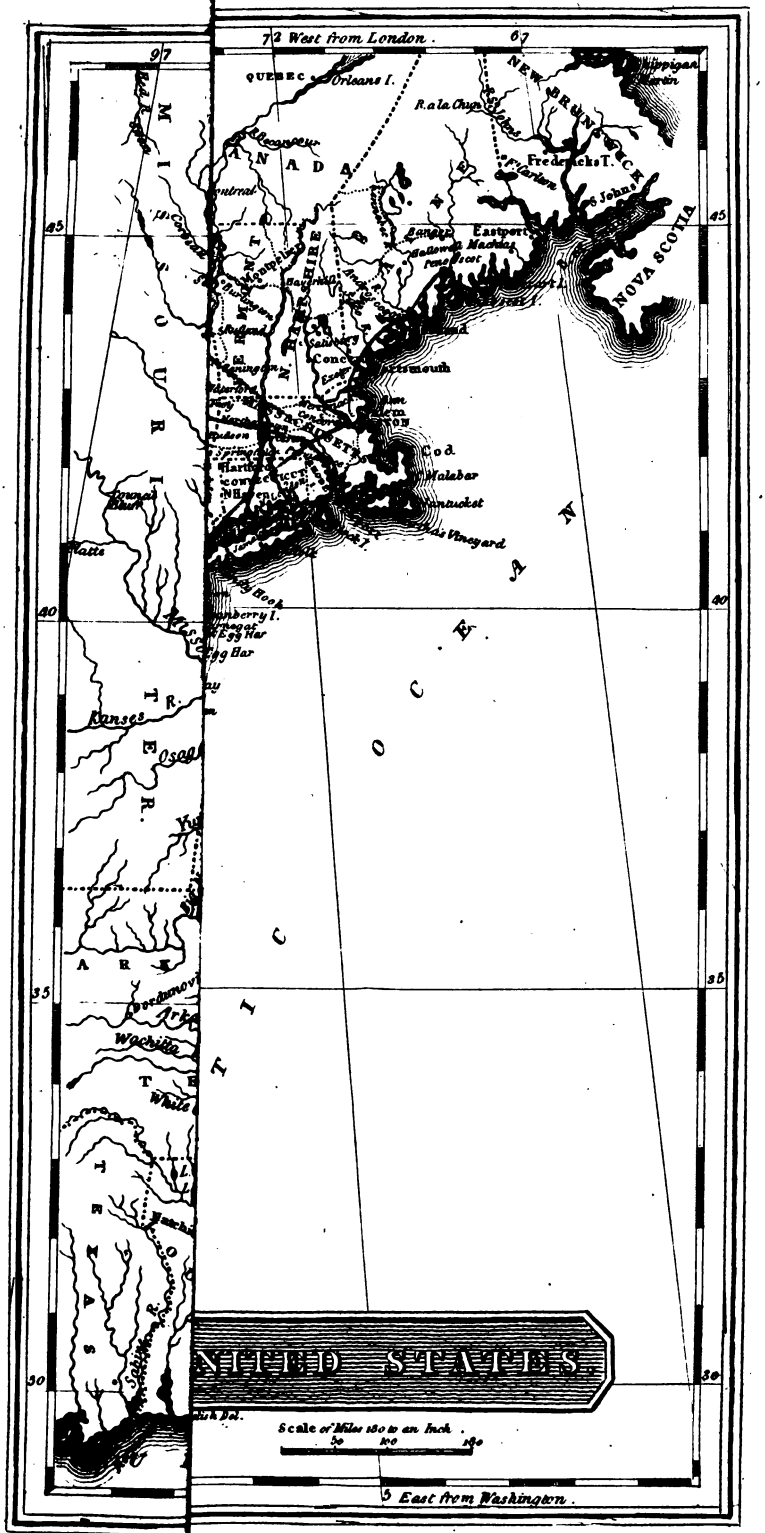

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inches, with proper bearings and unguents, a speed of 20 miles an hour, will injure neither wagons nor road.

On particular routes, with very large business, it may possibly be found advantageous to make an expensive road and use engines of considerable weight. Cheap and undulating roads, and light carriages, will, however, probably be most prevalent and profitable.

CHAP. VIII.

An Account of CANALS in the United States.

MAINE.

Oxford Canal. Extent 30 miles in a north-west direction to Sebago pond. Dimensions and cost not ascertained. Nearly completed.

MASSACHUSETTS.

Middlesex Canal. Length 27 miles in a northern direction from Boston to Chelmsford, on the Merrimack river. Dimensions 30 feet wide: 4 feet deep: lockage 136 feet. Cost 19,000 dollars per mile. Unprofitable. This is the first extensive canal completed in the United States. It was begun in 1790.

MASSACHUSETTS AND RHODE ISLAND.

Blackstone Canal. Length 45 miles from Worcester, Mass. to Providence, R. I., by the Blackstone river. Finished about two years since. Width about 30 feet: depth 4 feet: lockage 450 feet. Cost near 13,000 dollars per mile. Unprofitable.

MASSACHUSETTS AND CONNECTICUT.

Hampshire and Hampden Canal, and Farmington Canal. Extent about 87 miles from Northampton, Mass. to Farmington, Conn. and thence to New Haven. Expected to be in complete operation the present year.

NEW YORK.

Erie and Hudson Canal. Extent 362 miles from Albany to Buffalo. Width 40 feet: depth 4 feet: locks 90 feet long by 15 wide. Amount of lockage 679 feet. Begun in 1817. Finished in 1825. Cost above 20,000 dollars per mile. Profitable.

This canal has an aqueduct of 750 feet length over the Gennessee river: and three embankments 40 to 76 feet high, and in all, upwards of half a mile long, in the Irondequot valley.

Champlain Canal. Length 63 miles from Albany to Whitehall, on Lake Champlain. Dimensions of canal and locks the same as the last. Profitable.

Oswego Canal. Length 38 miles from Salina to Oswego, connect-

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ing the Hudson and Erie Canal with Lake Ontario. The locks are of wood. Unprofitable.

Cayuga and Seneca Canal. Length 20 miles, connecting the Hudson and Erie Canal with Cayuga and Seneca Lakes. Locks of wood. Completed in 1828. Unprofitable.

The four last mentioned are the property of the state. A state Canal is authorized from the south end of Seneca Lake to Elmira, on the Tioga or Chemung river, near the Pennsylvania line, a distance of 18 miles, in case it can be constructed for 300,000 dollars, with wooden locks.

Hudson and Delaware Canal. Extent 81 miles from the Hudson, near Kingston, to the Delaware at Carpenter's point, and thence up the latter stream to the mouth of the Lackawaxen, where it connects with canal and rail-way extending to the Lackawanna Coal Mines in Pennsylvania. Width 32 feet: depth 4 feet: locks 76 feet long and 9 wide. Cost near 16,000 dollars per mile. Begun in 1825. Completed in 1828.—Whole extent of canals in New York 564 miles.

NEW JERSEY.

Morris Canal. Length 100 miles 64 chains* by a circuitous route from Easton, Pa. to Newark and Jersey City near New York. It has numerous locks, and several inclined planes, which it is thought from experiments, will work well. The canal is intended for boats of 25 tons, and is expected to be finished this year.

Delaware and Raritan Canal. Incorporated in 1830. Extent about 30 miles from Trenton to New Brunswick. It is undetermined whether it shall be of sufficient capacity for sloop navigation.

PENNSYLVANIA.

State Canals. 1. From Bristol to Easton, on the Delaware, 78 miles. Width 40 feet: depth 5 feet: locks 90 feet long, 11 feet wide. 2. From near Columbia, on the Susquehanna, to Muncy hills on west branch of the same. Length 100 miles. 3. From Sunbury up the north branch of Susquehanna to Nanticoke falls, in the coal region, 59 miles. 4. From the mouth of the Juniata, to Huntingdon 90 miles. 5. From Johnstown, on the Conemaugh, to Pittsburg 104 miles. 6. French Creek Feeder, from Meadville to Conneaut Lake 19½ miles. Total 428½ miles. The dimensions, except on the Delaware, 40 feet wide: 4 feet deep: with locks 90 feet long and 15 and 17 feet wide.

About 200 miles of the above are navigable, and it is expected that nearly all the remainder will be completed the present year. Cost 23,030 dollars per mile.

Schuylkill Navigation. Extent 108 miles from Philadelphia to Port Carbon, in the coal region: 63 miles by canal, and 45 by dams and slack water. Locks 80 feet long and 17 feet wide, except the five uppermost, which are 13 feet 6 inches wide. Canal 36 feet wide. Begun in 1816. Navigable in 1825. Cost 21,000 dollars per mile, including water power from which considerable rents are received. Present prices of stock 61 per cent. above par.

Union Canal.—Extent 83 miles from the Schuylkill below Reading, to Middletown on the Susquehanna. Width 36 feet, depth 4 feet. Locks 75 feet long, and 8 feet 6 inches wide. Tunnel 18 feet

* Niles' Register, Feb. 28, 1829.—I have seen the length stated at 86 miles.

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wide, 16 feet high, and 729 feet long, being the longest in the United States. Cost upwards of $20,000 per mile. Completed in 1828. Not yet profitable. A navigable feeder of this canal, now nearly finished, extends up the Swatara to the Schuylkill Coal Mines.

Conestoga Navigation.—Length 18 miles from Lancaster to the Susquehanna River. Completed in 1823. Route circuitous. Dams 9 in number. Locks of wood, 100 feet long by 22 feet wide. Cost about $4000 per mile. Not yet profitable.

Lehigh Canal.—Length 46¾ miles from Easton to Mauch Chunk. Width 60 feet. Depth 5 feet. Locks 85 feet long in the clear; 22 feet wide. Amount of lockage 361 feet. Commenced in 1827; completed in 1829. Cost upwards of 25,000 dollars per mile.

This is probably the most perfect canal in America, if not in the world.

Lackawaxen Canal.—Extent 25 miles up the Lackawaxen Creek in Wayne county, uniting with the Delaware and Hudson canal, and belonging to the same Company. It was in operation in 1829. Adapted to boats of 25 tons.

Leiper Canal.—Extent a short distance from the Delaware river to the stone quarries of George G. Leiper, Esq., of Delaware county, by whom the work was executed. Finished in 1829.

Whole extent of canals in Pennsylvania, about 710 miles. Surveys have been made for a canal from Pittsburg to Erie, by way of the Beaver and Shenango, length 180 miles; for extension on West Branch of Susquehanna, from Muncy Hills to Bald Eagle creek, 46 miles; for do. on North Branch, from Nanticoke Falls to the New York line, 102 miles; and from Huntingdon to Frankstown, on the Juniata, 40 miles. These will probably be soon made, unless railroads shall be substituted in their stead. A route has been surveyed from the Lehigh, at the mouth of Wright's creek, to the Susquehanna, at the mouth of the Nescopeck. But the route is so circuitous, and the lockage is so great, that it probably will not be made.

DELAWARE AND MARYLAND.

Chesapeake and Delaware Canal.—Length 14 miles, from Delaware bay, below Newcastle, to Back creek, on Chesapeake bay. Width 60 feet; depth 10 feet. Locks 100 feet long; 22 feet wide. For sloop navigation. Commenced in 1823; finished in 1829. Cost about 150,000 dollars per mile.

There is a large and increasing trade on this canal, but owing to its great cost, the stock, which has rapidly risen, is yet below par.

The canal at one place has a deep cut 4 miles long, and 76 feet deep at the apex, being the deepest cut on any navigable canal in the world.

MARYLAND.

Port Deposit Canal.—Extent 10 miles from Port Deposit, up the Susquehanna river. Completed.

PENNSYLVANIA, MARYLAND, AND VIRGINIA.

Potomac, or Chesapeake and Ohio Canal.—Extent 360 miles from Washington city to Pittsburg. Width 60 feet; depth 4 feet. Tunnel in Somerset county, Pa., proposed to be 4 miles long. This canal is in progress between Washington and the Shenandoah river.

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VIRGINIA.

James River Navigation.—The navigation of this river has been improved by removing obstructions, and by occasional dams and locks, for a distance understood to be about 110 miles.*

VIRGINIA AND NORTH CAROLINA.

Dismal Swamp Canal.—Length 23 miles from Norfolk, Va. to Albemarle Sound, N. C. For sloop navigation. Completed and in operation.

SOUTH CAROLINA.

Santee Canal.—In progress. Extent 150 miles from Charleston, via Columbia, to Cambridge.

GEORGIA.

Ogeechee and Altamaha Canal.—Length 66 miles from Savannah to the Ogeechee and Altamaha rivers, through a favourable country. A part of the line is completed with wooden locks, at an expense of about $10,000 per mile.

OHIO.

Ohio State Canal.—Length 306 miles, by way of Cuyahoga, Tuscarawas, Muskingum, and Scioto rivers, from Cleveland, on Lake Erie, to Portsmouth, on the Ohio river. Begun in 1825. Now nearly finished; a part having been navigable for two or three years. Lockage 1185 feet. Cost of canal less than 10,000 dollars per mile.

It is proposed to connect the above canal with the Pennsylvania canal at Pittsburg, either by way of the Cuyahoga and Big Beaver, or by way of the Sandy and Little Beaver.

Miami Canal, Ohio.—Length 265 miles from Cincinnati, on the Ohio, to the lower Rapids on the Maumee of Lake Erie. Cost about 12,000 dollars per mile. Lockage from the Ohio to the summit 511 feet; from summit to the lake 378. Total 889 feet. The distance from Cincinnati to Dayton, about 70 miles, is navigable, and profitable.

INDIANA AND ILLINOIS.

Canals are contemplated to connect the Wabash river with Lake Erie, and the Illinois river with Lake Michigan. The National Government has made grants of land in aid of these works.

CHAP. IX.

Description of RAIL-ROADS in the United States.

MASSACHUSETTS.

Quincy Rail-Road.—From tide water near Boston, to stone quarries; distance 3 miles. Cost about 11,000 dollars per mile. Finished about 3 years since. Profitable.

A company is incorporated, to make a rail-road from Boston to the Connecticut river, near Brattleboro, Vermont, 160 miles, from whence it is proposed to extend it to Lake Champlain. Rail-roads

* 37 miles of canal 30 ft. wide 3 ft. depth; locks 16 ft. wide & 75 ft. long. Length the state is 40 ft. 50,000 tunnel.

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are also proposed from Boston to Albany, N. Y., and to Providence, R. I. The routes have been surveyed by direction of the legislature.

NEW YORK.

Albany and Schenectady Rail-Road.—Length about 18 miles. It is understood this work will be commenced the present season.

NEW JERSEY.

Camden and Amboy Rail-Road.—Extent about 65 miles from the Delaware, opposite Philadelphia, to Amboy, N. J. The stock of this company is already above par. The work will probably be commenced this year. The route will be up the Delaware as far as Bordentown.

PENNSYLVANIA.

Pennsylvania Railway.—From Philadelphia by way of Lancaster to Columbia, Lancaster county, on the Susquehanna river. Distance 84 miles. Cost about $15,000 per mile, if made with iron and stone. The graduation and bridging of 40 miles will probably be completed this year. Grade 28 feet to the mile.

Allegheny Portage Railway.—Length 38¼ miles from Frankstown to Johnstown, connecting the Pennsylvania canal. Estimated cost with tunnel, and locomotive and stationary engines, and self-acting planes, $936,000. Not to be commenced till 1831.

Mauch Chunk Railway.—Length 9 miles from the coal mine to the Lehigh river. Of wood and iron. Sleepers oak; rails pitch-pine. Iron plates ⅜ by 1½ inch. Cost of single track 3050 dollars per mile. Completed about 3 years since.

Schuylkill West-Branch Railway.—Extent 13 miles from Schuylkill Haven to the coal mines on the Broad mountain, (including a branch of 2½ miles). Commenced October 1st, 1829. The rails are now laying, and will be completed June 1st, 1830. Grade 27½ feet to the mile. Cost between 6500 and 7000 dollars for double track intended for locomotive engines. Sleepers white oak 10 to 12 inches broad. Rails white oak 4 by 7 inches. Iron ½ by 1½ inch. Width between the rails 4 feet 8½ inches. There are 54 bridges on the road, reckoning each arch as a bridge. Where the foundation is not rocky and solid, three trenches 18 inches wide and 18 inches deep are dug lengthwise of the road, and filled with large broken stone upon which the sleepers rest. These trenches serve as drains and keep the road dry.

For rapidity of execution and excellence and economy of plan and workmanship, this road probably exceeds any that has been made. It is worthy the examination of every person interested in, or curious concerning railways.

Engineer Mr. Sam. H. Kneass. Superintendent Dr. Benj. Kugler.

Mill Creek Railway.—Extent about 3 miles from Port Carbon, Schuylkill county, up Mill creek to coal mines. Single track. Rails wood 3 by 5 inches, covered with iron $\frac{5}{16}$ by 1¼ inch. Cost about 1450 dollars per mile including iron. In operation in 1829. It is intended to extend this railway up the Broad mountain.

Schuylkill Valley Railway.—Extent 10 miles from Port Carbon eastward up the valley of the Schuylkill nearly to its head. Graduation 27 to 54 feet to the mile. Rails of wood 3 by 5 inches, to be

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covered with iron. Double tracks. Cost near 3000 dollars per mile exclusive of iron. This railway was used last year for transportation upon the wooden rails. They are to be plated with iron the present year. The route passes through an abundant coal district. Superintendent Mr. —— Lawton.

There are lateral wooden railways connected with the above which cost 640 dollars per mile for single tracks.

Mount Carbon Railway.—Extent 9 miles of double way, from Pottsville up the Norwegian creek to the forks, and thence up the two branches to numerous coal veins. Rails wood, 6 by 8 inches, with iron plates ⅜ by 2 inches. Probable cost about 6000 dollars per mile, including half a mile of expensive arched foundation at the landing. Engineer Mr. William R. Hopkins.

Lackawaxen Railway.—Extent 16 miles from the termination of the Lackawaxen canal at Honesdale, Wayne county, to the coal mines at Carbondale, on the Lackawanna, passing through Rixes' Gap in the Moosic mountain. An ascent and descent of 1812 feet is overcome by 8 inclined planes; at 5 of which on the western side of the mountain, there are stationary engines. Cost about 12,000 dollars per mile, including engines, &c. In operation in 1829. Object, conveyance of coal.

Swatara Rail-way. Intended to extend from the head of the feeder of the Union Canal, to coal mines on the head waters of the Swatara.

Lykens' Valley Rail-road. Incorporated 1830. Intended to extend about 16 miles from the Susquehanna river, near Millersburg, in Dauphin county, to the coal mines in Dauphin and Schuylkill counties, near Gratz Town.

Beaver Meadow Rail-road. Incorporated 1830. To extend from the excellent coal quarries at the Beaver Meadow, Northampton county, to the Schuylkill, the Lehigh, or the Delaware, at the option of the company.

Little Schuylkill Rail-road. Extent about 18 miles from the mouth of the Little Schuylkill, up the valley of the stream to the coal mines at Tuscarora, Mauch Chunk, and Panther mountains. A branch is to leave the river near Greenfield, and pass north-westwardly through the Tuscarora mountain by a tunnel of near ⅓ of a mile. This rail-way is to be commenced about the present time, under the superintendance of Dr. Kugler. Will probably be completed next year.

Pine Creek Rail-road. To extend about 12 miles from the Sharp mountain, down Pine Creek, to join the Schuylkill at the mouth of Pine Creek. Not yet commenced.

DELAWARE.

New Castle and Frenchtown Rail-way. Extent 16 miles, to connect the Delaware with the Chesapeake, on the route between Philadelphia and Baltimore. The ground is now under survey, and the work will be promptly prosecuted.

MARYLAND.

Baltimore and Ohio Rail-way. Extent between 300 and 400 miles from Baltimore to the Ohio river, at a point not yet determined. The work is nearly completed for about 13 miles. In progress for

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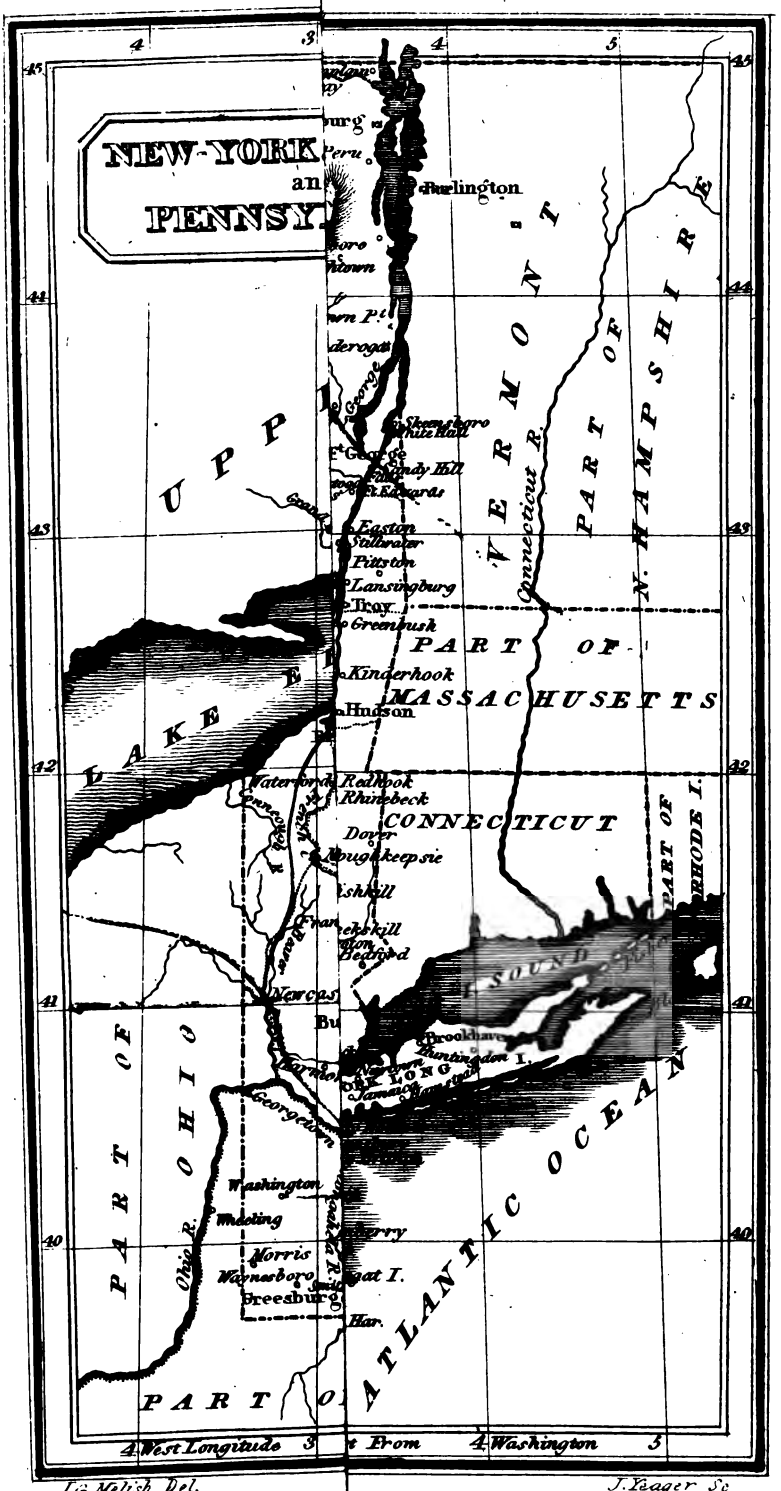

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about 53 miles further. Cost of the first 13 miles, between 50,000 and 60,000 dollars per mile. Estimated cost for the whole distance 22,000 dollars per mile.

Rails of pitch pine, supported upon cedar sleepers, and plated with iron ½ inch by 2 inches. For locomotive engines.

Baltimore and Susquehanna Rail-way. Intended to extend from Baltimore to the Susquehanna, at Pennsylvania line, with a branch to York, Pa. About 60 miles.

SOUTH CAROLINA.

Charleston and Hamburg Rail-way. Extent about 150 miles from Charleston to Hamburg, on the Savannah river. Rails of iron, supported on stone. Cost not ascertained. A part of the line is understood to be completed.

KENTUCKY.

Lexington and Ohio Rail-way. Incorporated. To extend from Lexington to the Ohio river, probably at Louisville, or at Maysville. Stock subscribed 1830.

CHAP. X.

Suggestions for Future Improvement.

The sections of country on which artificial improvements are both most desirable and profitable, are those between which considerable intercourse subsists, or may advantageously be established: but between which natural channels of navigation do not subsist, or are very circuitous.

Upon a glance at the map of the United States, there are three great routes which strike the eye as those on which rail-roads would be particularly advantageous and probably lucrative.

The first of these starts at the Mississippi river, near the lead mines in the north part of Illinois, and proceeds eastwardly over the table land of Illinois, Indiana, and Ohio, to the western part of Pennsylvania, whence by diverging lines, it may communicate with tide water on the Potomac, the Chesapeake, the Delaware, and the Hudson. *See the yellow line on the map of the United States.* It communicates with Lake Michigan, with steam boat navigation on the Wabash and Illinois, and with the Ohio canals.

The country for the greater portion of the distance, is extremely favourable, being on the height of land between the Ohio and the Lakes, crossed by few streams, and the land extremely level.

The comparative distances to tide water by rail-way, and by water communication, from various places on the route, may be seen in round numbers in the following

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TABLE.

	By rail-way.	By water.	Difference.
From lead mines,	900 miles.	near 1800	900
Head of Lake Michigan,	750	1350*	600
Head waters of Illinois river,	700	1800	1100
Head of Wabash,	600	1900	1300
Summit of Miami Canal,	560	770*	210
Do. Tuscarawas Canal, Ohio,	420	590*	170

The distances where a * is annexed, are reckoned through the New York canal, which would require trans-shipment, as well as a dangerous lake navigation; and they are reckoned only to Albany.

The construction of the abovementioned rail-way, would increase the value of United States' lands to the full cost of the work.

The country through which it would pass, is an extremely fertile one: and a great portion of it is so level, that the road might be nearly straight. The greater part of the lead, of which 12 millions of pounds per annum, are already dug, would pass by the rail-way, and the communication with navigable waters and canals would create an immense business.

The second route suggested, is one to connect the head waters of the Tennessee river with the Atlantic at Richmond, Washington, Baltimore, and Philadelphia. (*See the route in map.*) The road should extend to steam navigation, say the junction of the Holston and Clinch: another rail-road should extend from the Tennessee to Tuscaloosa, Alabama, connecting with steam navigation by the shortest route to Mobile: from the latter place a rail-road might be carried to New Orleans.

A branch might extend to the gold region in North Carolina; and another through Cumberland gap to the Cumberland river in Kentucky.

The distances from the head waters of the Tennessee, Cumberland, and Kenhawa rivers to tide, by way of New Orleans, vary from 1900 to 2300 miles. By the rail-way, they will be from 400 to 600 miles. The rail-way should extend to the Susquehanna in Pennsylvania, so as to intersect with the canals and rail-ways made, or in progress, to extend to Richmond, Washington, Baltimore, and Philadelphia.

The third route would extend from Portland, or Wiscasset, in Maine, to Milledgeville, Georgia, for the accommodation of the populous towns in the vicinity of the Atlantic coast. In case of war, the business of such a road would be incalculable, and its utility most important. At all times the number of passengers on the route, would probably be sufficient to pay for a reasonably constructed rail-road. These, added to the conveyance of light goods, and in many cases heavy goods, would make the road very profitable.

Among the places accommodated, would be Portsmouth, Newburyport, Salem, Boston, Providence or Hartford, New Haven, New York, Newark, New Brunswick, Trenton, Philadelphia, Wilmington, Port Deposit, Baltimore, Washington, Alexandria, Fredericksburg, Richmond, Petersburg, Fayetteville, Raleigh, Columbia, Augusta and Milledgeville. Distance about 1400 miles: of

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which 640 north of Washington, and 760 south. *See the route on the map.*

The country would generally be very favourable, except that the expense of bridges would be great.

The three routes above named, would amount, including a branch through New York, from Ohio to Albany, to about 3300 miles, and could be made for a sum of from 33 to 40 millions;* a large sum, but not burthensome to the large section of country which would be benefited.

The execution by the national government, if within its authority, would be very easy in a period of less than 10 years. If it be the final deliberate determination of Congress and the people, that the execution of such works is within the power of the national government, with the consent of the states through which they pass, then undoubtedly an extensive and liberal system is the most proper and fair one.

The above works might be executed upon the conditions that the tolls to be collected by the national government, should not exceed a profit of 6 per cent.: and that the states should have the privilege of purchasing at cost, and charging the same toll.

CHAP. XI.

Suggested Improvements in Pennsylvania.

Though Pennsylvania has already a great extent of Canals and Rail-roads, yet she has more inducements to make further additions than can be found in perhaps any country. The chief supports of canals have been the mineral productions of the earth. Wherever they were abundant, canals have been profitable.

Coal, salt, and iron are the species of those productions which are most used. Pennsylvania has its anthracite coal, in abundance of quantity, excellence of quality, and facility of mining, unequalled upon the face of the earth. She has bituminous coal of excellent quality and inexhaustible quantity, extending from Bradford county, on the New York line, to Somerset, on the Virginia boundary, and covering a great portion of country west of the Alleghany mountain. Salt also, is found from Susquehanna county† in the north, to Bedford in the south, and in various portions of the western section of the state, coal being always found in the vicinity, with which to boil the salt water. Iron may be profitably worked in perhaps a majority of the counties of the state, the quality being generally superior. There is much good land, and abundance of lime stone, which may be conveyed on rail-roads to fertilize that which is less productive. The state has an Atlantic city, of which its founder said there was not one on the earth better seated; and a thriving western city, possessed of great advantages both for manu-

* A double rail-way *for horses*, might be made for 13 millions.

† The salt water on the Wyalusing creek, Susquehanna county, is said to be even superior to that at Salina, New York.

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factures and commerce. The mineral wealth, and the abundant water power of Pennsylvania, must make it a country abounding in manufactures, which are an important auxiliary to the productiveness of rail-roads.

The most convenient outlet to the ocean, from the very fertile country extending westward from the Alleghany to the Mississippi, lies through Pennsylvania. That country, having little water power, will probably always export largely of agricultural produce, and import largely of manufactures. Its business alone would occupy a rail-road through Pennsylvania.

Such a state cannot err, nor lose, by extending rail-roads, on an economical plan, through every county.

The first desirable line that I shall notice, is one to connect Lake Erie with the ocean. It has been proposed to establish a communication by canal to Pittsburg, by way of the Shenango and Big Beaver Creek, a distance of 168* miles. This route would afford a slender prospect of business to pay for the construction of the canal. The distance from Erie to Philadelphia, by the route and the Union Canal, would be 589 miles, with two trans-shipments at the Alleghany Rail-road: while the distance from Lake Erie, to tide water at Albany is but 362 miles by canal, and produce could come to Philadelphia cheaper that way, than by Pittsburg.

A rail-way of less than 200 miles through the northern counties, to the present termination of the Pennsylvania Canal, at the Muncy Hills, at the Lycoming county line, could be made for horses at $3500 per mile, less than one-third the probable cost of the canal to Pittsburg; and the distance to Philadelphia, by this route, would be one hundred and forty miles nearer than the other, and the transportation cheaper in proportion, if toll were charged according to the expense. Not a stationary engine would be required on the route. It might go by Pine Creek and Coudersport, or by the Driftwood branch of the Susquehanna. Or it might proceed by Bennett's branch of the Susquehanna, and the north end of Elk mountain, in Clearfield county, to Toby's Creek, Hemlock Creek, and Oil Creek, in Crawford and Venango counties. The last route might require a stationary engine. Either course would accommodate parts abounding in bituminous coal, iron and salt.

Another route, which would accommodate a more settled country, and perhaps more rich in minerals, would leave the Susquehanna at Selinsgrove, Union county, and pass by Penn's Creek Valley to Bellfonte, thence to Phillipsburg, Curwinville, &c. in Clearfield county, thence to the mouth of the Mahoning, on the Alleghany river; thence westward to the Ohio line. This might intersect a road from Erie to the mouth of Kiskiminetas, which would accommodate trade going either to Pittsburg or Philadelphia. The only difficulty on this route, would be the Alleghany mountain, which would be crossed obliquely, at a lower place than those further south. The iron, coal, and salt on the Alleghany river, and the country toward the Susquehanna, would make this route profitable, without other aid. The Clearfield county bituminous coal might be brought by it to Philadelphia, lower than the Richmond coal is sold.

A second object of importance, would be the accommodation of

* 186, if by way of French Creek.

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the south-western counties, by continuing the rail-way from Columbia, Lancaster county, to Washington, Pa., with a branch to Pittsburg. This route would have numerous passengers, a great winter trade, and would bring the business of the south-western counties to Philadelphia. It might pass through the Blue mountain at M'Allister's gap, at Roxbury, Franklin county, through Sideling hill by the gap of Sideling hill creek, at the Bedford and Huntingdon line, and through Chesnut hill, by the head of Jacobs creek. There would be still the Tuscarora, the Alleghany, and the Laurel mountains to pass. With a liberal ascending and descending graduation, however, there would be no very serious difficulty, self-acting planes being used on the Alleghany. Perhaps, as this route is not very distant from the canal, a *single* rail-way for steam engines might answer.

A third primary object would be the formation of a near connexion between Philadelphia and the Anthracite Coal Region of Schuylkill, Northampton and Luzerne counties, as well as the region of salt and bituminous coal in Susquehanna, Bradford, and Tioga counties.

If coal can be delivered at Philadelphia as cheap as it is sold in Liverpool, the annual quantity sold will amount to millions of tons; and the Schuylkill and Lehigh navigation will be insufficient for its transportation.* The best coal is sold at Liverpool at 15 shillings per ton, equal to $3,33; or, to $3,60, if the difference of gold and silver currency be considered. Notwithstanding a heavy export duty, large quantities are shipped. Let us see if coal can be delivered as low at Philadelphia. We will take the Luzerne county coal, which is the most distant anthracite. That coal can be mined at 40 cents per ton, the veins being nearly horizontal. If sold at 80 cents it will pay a handsome profit. The distance to Philadelphia is 100 miles in a right line. We will suppose it 120 by a rail-road, on the best route. The coal being 700 feet higher than Philadelphia, the transportation will be cheaper than if they were both on a level.

Suppose an engine to go and return in 3 days, carrying 40 tons.

Engine 3000 dollars,—20 per cent. per annum, for interest and repairs for 3 days,	6 00
Wagons for 40 tons, at 2000 dollars,—20 per cent. per annum, is for 3 days,	4 00
2 men and 1 boy, at $3,50 per day,	10 50
Tallow and oil,	1 50
Coal for engine, 4800 lbs., say 2⅙ tons, at 80 cents,	1 74
Total for transportation of 40 tons,	$23 74
Add cost of 40 tons coal at 80 cents,	32 00
Toll at 60 cents per ton, on 40 tons,	24 00
Total cost of 40 tons at Philadelphia,	$79 74

$79,74, say $2 per ton.

Three dollars per ton at Philadelphia, will certainly afford a profit, if the toll be at 60 cents. Suppose the rail-road to cost one million of dollars, rails being wood and iron, graduation 60 feet per mile one way, and 40 the other; then 400,000 tons at 60 cents, would pay

* Near two millions of tons per year are shipped from the neighbourhood of Newcastle, England. The quantity mined in that country probably amounts to five millions of tons yearly.

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240,000 dollars per year, or 24 per centum, in addition to a large income from passengers.

By such a road, the coal of Luzerne can be rendered valuable; but the great distance it now travels to market, gives other coal so much advantage, that it is nearly useless.

A very eligible route to the coal regions, is, to follow the Schuylkill and Little Schuylkill to the source of the latter, then descend the Catawissa creek to the bend on this side Bucks mountain, thence pass eastward to Black creek and through its gaps in the Bucks and Nescopeck mountains to the Susquehanna, at the mouth of the Wapwallopen. *See the Maps of Tanner or Melish.* A branch could extend to Catawissa, and thence to Pennsborough, uniting with the line to Lake Erie.

But a more direct route would be from Philadelphia by the best course to the head waters of the Perkiomen or Manatawna, in Berks co., near numerous iron works and iron ore; thence to the Blue mountain, about 8 miles east of the Hamburg gap, where is a favourable place for a tunnel of half a mile;* thence crossing the Little Schuylkill to Greenfield, and through the tunnel making in the Tuscarora mountain; thence directly north to Catawissa creek, passing the Broad mountain east of the head of Mill creek and Little Mahanoy. A tunnel of ⅓ of a mile through coal in the Mahanoy mountain would be needed, for which the coal passing out would pay at a small toll. This route would be 20 miles nearer than the former, and would cost much less.

The above route would be 120 miles to the coal mines, to which the distance by the Union and Pennsylvania canal is 265 miles.

From the mouth of the Wapwallopen to the New York line, the best route would probably be up Shickshinny creek, and over the table land at the sources of the Loyalsock creek, thence down the south branch of the Towanda creek. A survey, however, would determine the question.

It would be advisable for the city and liberties of Philadelphia, and the county of Luzerne, to make the above railway, if authorised, as it would be of immense importance to the citizens of each county.

The contemplated canals of 186 miles from Pittsburg to Erie: 46 miles from Muncy hills to the Bald Eagle, and 102 miles from Nanticoke falls to Tioga point, would, at 15,000 dollars a mile, cost 5 millions and 70,000 dollars. Rail-ways might be put thus:

Double rail-way to Susquehanna, north branch, 120 miles, at 8000 dollars per mile.	$960,000
Do. thence to Tioga point, 80 miles for horses, at 3000 dollars,†	240,000
Double rail-way from Susquehanna to Lake Erie and Ohio line; say, with branches, 250 miles, at 8000 dollars,	2,000,000
Single rail-way from Columbia to Washington, Pa. for steam power; say, at 5000 dollars per mile, 260 miles,	1,300,000
Total,	$4,500,000

* The author has personally examined the route, and found it very favourable. The mountain called the Red mountain on some maps, has no existence at the place of crossing, and there are numerous gaps in Summer Hill.

† Lumber will be so cheap on this route, and on that to Erie, that the estimates are probably full large.

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Being less than the cost of the fore mentioned canals. The surplus would make a double rail-way from Pittsburg to the Ohio line, to connect with the Ohio canal, at the mouth of Sandy creek.

A branch road should be extended in Luzerne county, up the Susquehanna and Lackawanna, perhaps to the Great Bend. A branch should also extend from the neighbourhood of Kutztown to Allentown.

A very direct route from Philadelphia to Lake Erie, would be to go to Reading; thence to the Blue mountain, at the head of Little Swatara, crossing by a tunnel; thence to Pine Grove, Klingerstown, the mouth of the Mahanoy, New Berlin, Belfonte, Curwinville, Franklin, &c. The country, for nearly the whole distance, would be rich in mineral wealth. The rail-way from Franklin to Erie, would give a communication to Pittsburg by steam-boats on the Alleghany. The distance from Philadelphia to Lake Erie, by this route, would not exceed 360 miles.

CHAP. XIII.

A Brief Description of the Anthracite Coal Region of Pennsylvania.

The Anthracite Coal Region occupies a part of Dauphin, Northumberland, Columbia (probably), Schuylkill, Luzerne, Northampton, and Wayne counties. Its southern extremity is the mountain called at different places, Sharp, Tuscarora, and Mauch Chunk mountain. The coal occupies the northern, but not the southern half, or side of the mountain. Its northern boundary is toward the sources of the Lackawanna, near Belmont, in Wayne county. Its eastern boundary may be considered as the Lehigh river, and a line drawn north of it; and its western boundary the main branch of the Susquehanna, although it does not extend quite to that stream, nor to the Lehigh, so far as ascertained. Its greatest extent from east to west, is about 70 miles; from north to south about 70 miles; and from north-east to south-west 130 miles. Its width from south-east to north-west, varies from 3 to perhaps 25 miles.

The following table shows the value of the coal of this region, compared with that of other parts, as deduced from the experiments of Mr. Marcus Bull. The numbers show the time in hours and minutes that a certain degree of heat was maintained by 1 lb. of coal of each kind.

	H.	M.	
Lehigh coal,	13	10	Penn. Anthracite.
Lackawaxen,	13	10	
Schuylkill,	13	40	
Susquehanna,	13	10	
Swatara,	11	20	
Rhode Island,	9	30	
Karthans, Pa.	9	20	
Worcester, Mass.	7	50	
Richmond, Va.	9	20	
Stony Creek, Pa.	9	50	
Cannel,	10	30	
Liverpool,	9	10	
Newcastle,	9	20	
Scotch,	9	30	

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The Pennsylvania anthracite region has been generally divided into three districts. 1. The southern, extending from the Sharp to the Broad mountain, inclusive: 2. the Middle or Beaver Meadow, extending from the Spring mountain to the Bucks mountain, and which should probably include that on the north side of the Mahanoy creek from its source, to within 6 miles of its mouth: 3. the northern, commencing on the Susquehanna, near Berwick, and extending up the valley of that stream to Pittston, and thence up the Lackawanna, to Belmont, Wayne county. The country, however, has not been sufficiently explored to determine whether any complete line of division exists between these tracts. Considering these as distinct tracts, each tract would be about 70 miles in length, and from 3 to 9 in width; the veins running lengthwise from south-west to north-east.

The coal is found in veins varying from a few inches to near 50 feet in thickness. The average thickness is about 10 feet. The veins, lengthwise, run generally in the same direction with the mountains and valleys. They slope or dip toward the south, the upper edge being northward. Their inclination varies from nearly horizontal, to nearly vertical.

At the Mauch Chunk, Beaver Meadow, and Mahanoy mines, the coal is found in immense masses, and may be quarried in open air at an expense of from 15 to 30 cents a ton. The large horizontal veins near Wilkesbarre; are mined by leaving coal pillars to support the slate roof, at an expense of 30 to 50 cents. The mines on the Schuylkill are worked by running horizontal shafts, or tunnels, into the veins at the foot of the hills, and from these working upwards in the vein toward the surface of the hill, the coal sliding down a *schute*, and passing out on a rail-road in the tunnel. The expense of mining here, is now about 80 cents; but will probably be reduced to an average of 50 cents.

The middle and south-eastern portions of the region, furnish the hardest and heaviest coal. That toward the north and the west, contains much hydrogen gas, and burns freely and with flame.

The quantity of coal is inexhaustible.* There are supposed to be 8 veins 50 miles in length, in the Broad mountain alone. In working it, none of the difficulties of raising coal by steam power, and pumping water, are encountered.

The quality of the coal and its cleanliness are such, that those who have tried it, will use none other.

The altitude of the coal varies from 600 to 1500 feet above tide water. If the descent were uniform, rail-roads might be so constructed, that the coal would descend of its own gravity to tide water.

The limits of this work, already extended beyond the intention of the author, prevent further observations. A Statistical and Geological view of the Coal Region, is proposed to be shortly published by Mr. James S. Wallace, which will probably afford the public interesting information.

* The North American Coal Company have dug 45,000 tons of coal from six acres of land, the last 3 years. It is supposed there are from 400,000 to 600,000 tons more on the six acres. On Serby's run, 9 miles east of the Susquehanna, on the north of Big Mahanoy creek, in Northumberland county, a horizontal vein or mass is found near one mile in width, and fifty feet in depth, of very pure coal. The Beaver Meadow and Mauch Chunk mines present analogous phenomena.

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